BISCHOFF RESERVOIR ENHANCEMENT FEASIBILITY STUDY

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BISCHOFF RESERVOIR LAKE ENHANCEMENT STUDY

EXECUTIVE SUMMARY

The objectives of this feasibility study were to assess the current eutrophication-related problems of Bischoff Reservoir, identify the sources of the problems and their relative contributions, and develop recommendations for a restoration program to improve the water quality of the reservoir.

Located in Ripley County, Bischoff Reservoir has a surface area of 190 acres, a mean depth of 8.1 feet, and a 2,980 acre watershed. Most of the drainage from the predominantly agricultural watershed enters the reservoir through five tributaries that are along two branches of the reservoir: a northern branch and a southern branch. The drainage is east to west towards a dam; the dam is 27 to 30 feet high.

Since its construction in 1963, the water quality and general condition of Bischoff Reservoir has declined. In the mid-seventies, the Indiana Department of Environmental Management (IDEM) determined that Bischoff Reservoir had a Eutrophication Index (EI) value of 63 (on a scale of 0 to 75). At the time this report was prepared, an EI value of 47 was calculated. Although this value is lower than the 63 previously calculated by the IDEM, the 47 indicates that there is still a high level of deterioration in the reservoir's trophic condition.

Based on its trophic status, Bischoff is a Class Two (intermediate quality, intermediate level eutrophic) reservoir, meaning that Bischoff Reservoir appears to be aging. Class Two lakes are usually productive and support extensive concentrations of macrophytes and algae. Siltation appears to be a major problem in the reservoir. Based on visual reconnaissance, it appears that 10 surface acres have been lost over the last 28 years. Other problems in the reservoir include nutrient loading, gas bubbles, and algae scums collected on screens in the water treatment plant. Lake users report that boating and fishing are hampered during periods when the algae is in high bloom.

The reservoir water quality data collected was characteristic of shallow productive reservoirs. Top layered sediments are composed primarily of hydrocarbons and organic materials with silts and clays. A distinct flocculent layer at the surface of the reservoir bottom appears to consist largely of dead algae cells and hydrocarbons.

Significant sources of sediment and external nutrient loading into Bischoff Reservoir include urban infrastructure, land use, and agricultural activities. Urban non-point source pollution results from activities in and around the town of Morris. The town does not have a sanitary sewer system and the types of soils in the area are such that the septic fields currently in use would experience high water levels during the spring of each year. These septic fields may leak, as indicated by the fecal coliform values found in Bischoff Reservoir. Agricultural pollution results from erosion-causing farming practices and from runoff of fertilizers and pesticides. In addition, livestock access to inlet streams (on all the inlets) results in streambank erosion and in the deposition and transport of waste directly into streams, where it can flow unchecked into Bischoff Reservoir.

Restoration of Bischoff Reservoir must include a significant reduction in the degree of both internal and external nutrient loading to the reservoir. Several actions should be considered to improve the condition of Bischoff Reservoir. Priorities for implementation of these actions are:

1. Implementation of Best Management Practices (BMP's) throughout the watershed coupled with extensive educational programs designed to make local residents aware of how various types of land uses affect water quality in Bischoff Reservoir. This should include the selection and implementation of appropriate animal waste management systems, erosion control practices, and fertilizer reduction practices.

2. The installation of sanitary sewers and treatment facilities in the town of Morris to improve the quality of Bischoff Reservoir.

3. Initiation of an "over winter" reservoir drawdown to oxygenate sediments, "freeze out" aquatic vegetation, and consolidate loose organic sediments. Drawing the reservoir down by at least five feet would expose most of the organic sediments. A drawdown would also be beneficial by helping to increase the depth in embayment areas.

4. The installation of limestone sediment traps at the southeastern and northeastern inlets to the reservoir should also be considered to provide filtration, but only after implementation of controls for the fecal coliform levels.

While actions to reduce both internal and external nutrient loading are important, significant reductions in external loading could make in-reservoir actions unnecessary. A significant reduction in external loading would cause the reservoir to export nutrients to a new equilibrium between nutrient inputs and losses. The detention time of the reservoir is in excess of five months which would allow flushing two to three times per year. The new trophic conditions could enhance the condition of the reservoir.

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1.1 - STUDY OBJECTIVES:

The objectives of this feasibility study were to assess the current eutrophication-related problems of Bischoff Reservoir, identify the sources of the problems and their relative contributions, and develop recommendations for a restoration program that would improve the quality of the reservoir.

This effort included a compilation of historic water quality, land use, and hydrologic data (Section 2.1); a field survey and sampling program (Section 2.2); an analysis and evaluation of all data (Section 3); an identification of appropriate technological solutions (Section 4); and a presentation of conclusions and recommendations (Section 5).

1.2 - BISCHOFF RESERVOIR AND WATERSHED:

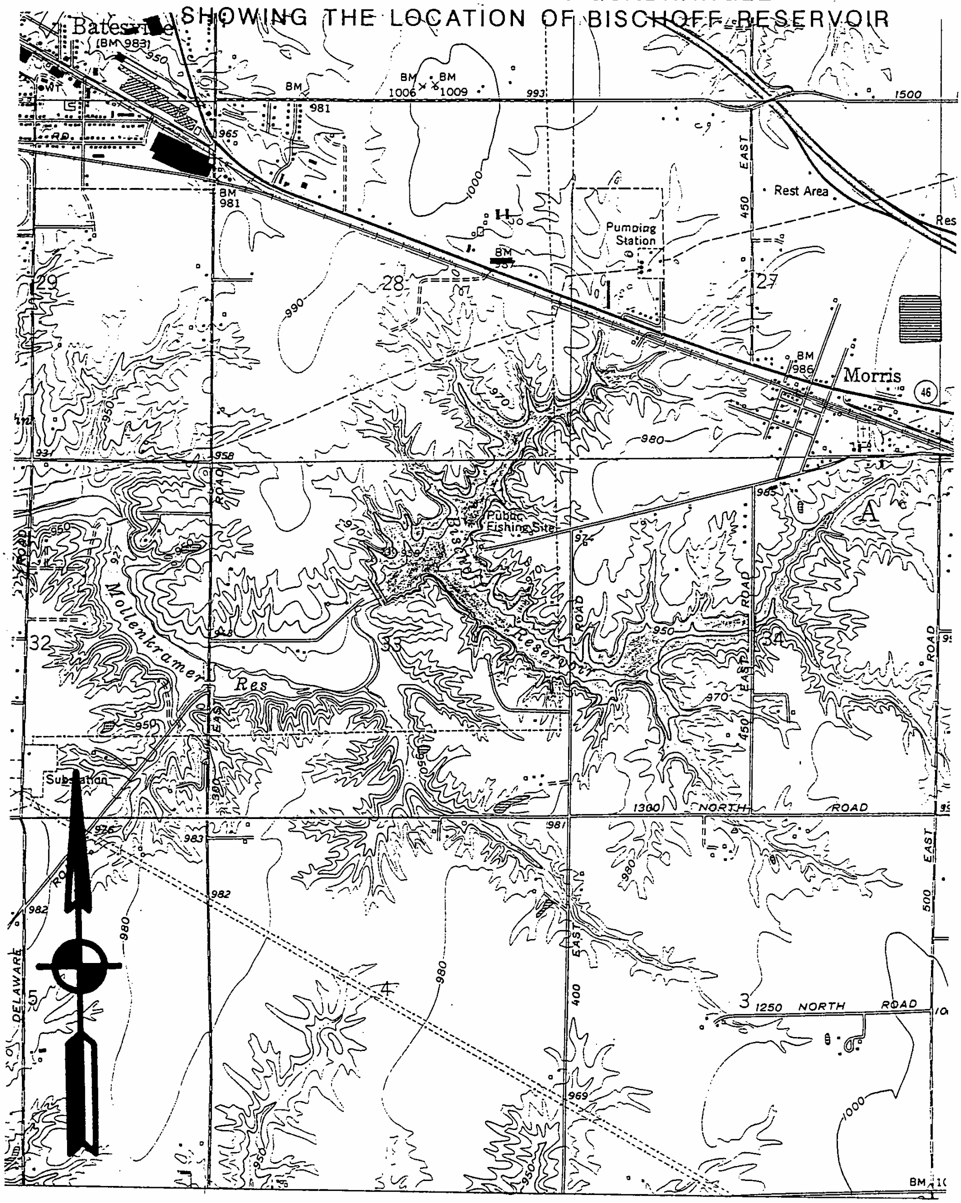
Bischoff Reservoir was constructed by the Batesville Water and Gas Company in 1963. The reservoir was constructed to supply raw water to this utility, since the downstream Mollenkramer Reservoir had silted to a depth of about six feet. Located in Ripley County, Bischoff Reservoir has a surface area of 190 acres and a mean depth of 8.1 feet. Figure 1 shows the location of Bischoff Reservoir. The 2,980 acre watershed is predominantly agricultural, and most of the drainage enters the reservoir through two major branches. The northern branch has two inlets; the southern branch has three major inlets. The northern branch drains areas along State Road 46, which includes subdivisions and the community of Morris, an unincorporated town. The northern shoreline of the reservoir is developed with single family residences. A public access site on the eastern portion of the reservoir (as noted on Figure 1) has a concrete boat ramp.

The reservoir discharges into a five foot by five foot vertical drop intake structure and passes through a 48 inch discharge pipe with an outfall headwall section. The 48 inch pipe is approximately 160 feet long. A 27.5 foot high drop structure tower is located at elevation 947.43.

The reservoir initially had a depth of 27 feet at its deepest point with an average depth of 9.6 feet. The bottom of the reservoir was relatively firm. Aerial photographs taken in the early 1960's indicate that the reservoir was surrounded by farmlands during the community's early stages of development. Recent development consists of new subdivisions on the northern shoreline.

Figure 1

PORTION OF THE BATESVILLE QUADRANGLE SHOWING THE LOCATION OF BISCHOFF RESERVOIR



SCALE 1:24 000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

CONTOUR INTERVAL 10 FEET

NATIONAL GEODETIC VERTICAL DATUM OF 1929

With respect to capacity, the Batesville Water and Gas Utility Company reported that the present pumping rate from the reservoir to the Liberty Park Upland Storage Area is approximately 850 gallons per minute (GPM). This equals approximately 1,371 acre feet per year of raw water.

The average evaporation is 28 inches per year (or approximately 467 acre feet) from the reservoir surface. Analysis of rainfall (see Table 1) characteristics in Indiana indicate that for this watershed, runoff amounts to approximately 13.5 inches (or approximately 3,127.5 acre feet of the annual rainfall). The direct rainfall on the reservoir is 39.5 inches or 658 acre feet of water per year. This amounts to a net annual gain of 11.5 inches or 190 acre feet of precipitation directly on the reservoir water surface.

As previously determined, the 850 GPM rate equals 1,371 acre feet in a given year. This leaves an extra 174 acre feet for pumping which amounts to 108 GPM. Therefore, the pumping rate could extend to 958 GPM to balance an average year. Bischoff Reservoir has enough water to withstand a 213 day drought. Water at eight foot and at fifteen foot depths should be used for intakes for water to be pumped to Batesville Upland Storage Reservoir at Liberty Park.

As of August 1989, Morris had approximately eighty residences, a church, a large cemetery, four stores, a feed mill, and a restaurant/tavern. Based on the zoning map (Figure 2), increased development of single family homes is projected for the northern branch of Bischoff Reservoir. New development would be serviced with a sewer system instead of the septic field systems currently in use in Morris.

A major portion of the surrounding watershed is devoted to farming operations including three large feedlots, two of which are for hogs, and one for cattle. These feedlots are ten acres or larger. Figure 8 on page 22 shows the location of these feedlots.

A large truck terminal located on the north side of State Road 46 drains to the east into an inlet of the reservoir. This inlet is near a major petroleum line pumping station of the Panhandle Eastern Pipe Line Systems. The pump station has diking systems, and at this time no spills have occurred. The main controls are located in Seymour, Indiana which allows the piping system to be cut off. It takes about thirty minutes to shut down the pipe line system.

A newly constructed roadway, State Highway 129, runs north and south through the study area in the northern portion of the watershed. This roadway was constructed by the Indiana Department of Transportation in 1990. Figure 3 identifies the route of highway 129.

Table 1

TEMPERATURE AND PRECIPITATION

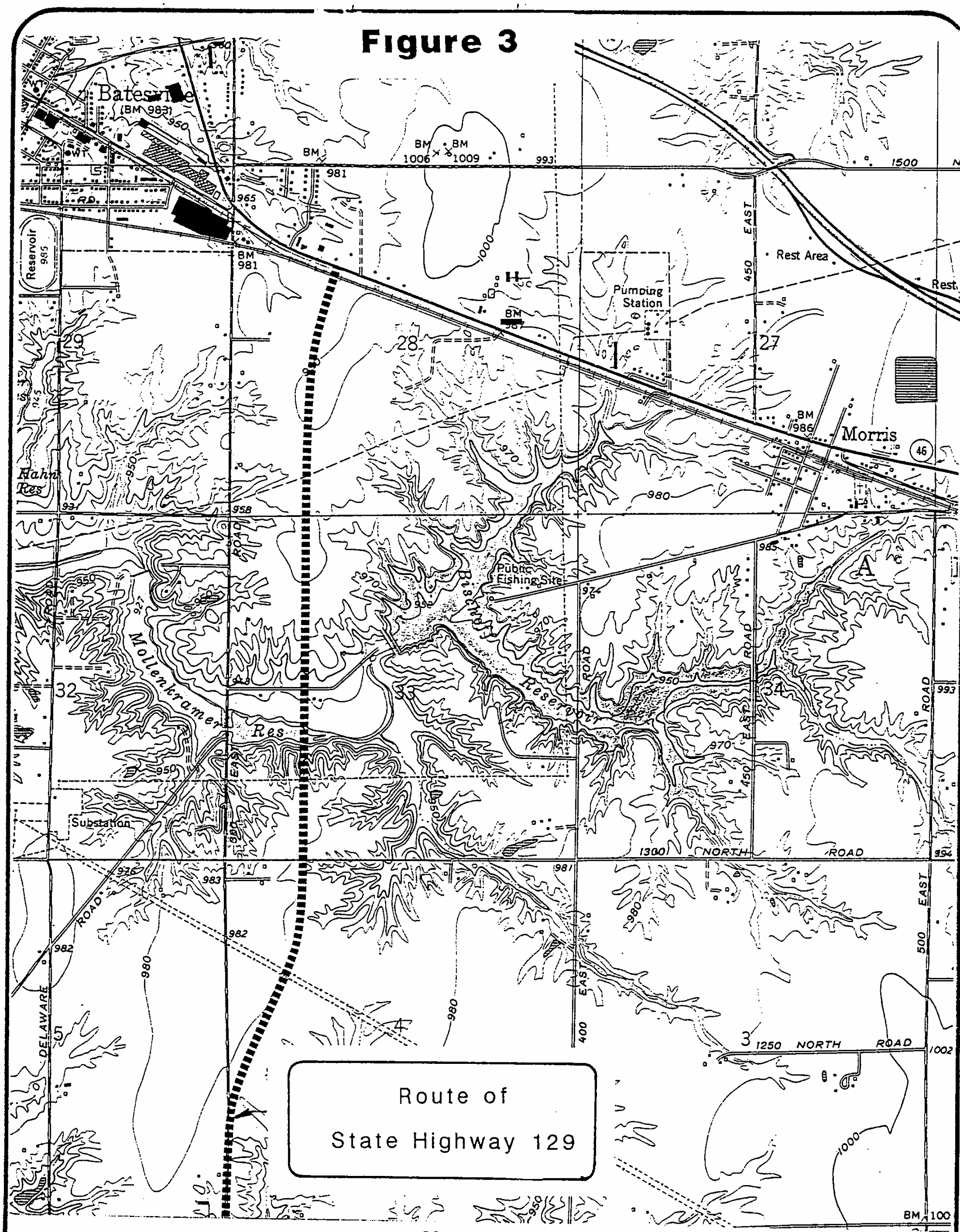
[Recorded in the period 1951-76 at Greensburg, Indiana]

Month	Temperature						Precipitation				
	Average daily maximum	Average daily minimum	Average	2 years in 10 will have-- Maximum temperature higher than--	2 years in 10 will have-- Minimum temperature lower than--	Average number of growing degree days*	Average	2 years in 10 will have-- Less than--	2 years in 10 will have-- More than--	Average number of days with 0.10 inch or more	Average snowfall
	°F	°F	°F	°F	°F	Units	In	In	In		In
January----	38.1	19.1	28.6	66	-17	21	2.61	1.23	3.74	5	4.4
February---	42.3	22.3	32.3	67	-11	40	2.60	1.04	3.84	5	3.3
March------	51.4	29.9	40.7	78	5	170	3.67	1.70	5.27	7	3.6
April------	64.6	40.4	52.5	84	19	379	4.14	2.18	5.74	9	.2
May--------	73.9	49.2	61.6	90	26	670	4.62	2.42	6.41	8	.0
June-------	82.4	58.1	70.3	95	39	909	3.99	2.41	5.40	7	.0
July-------	85.6	61.1	73.3	96	44	1,032	4.23	2.29	5.82	7	.0
August-----	84.4	58.7	71.6	96	43	980	2.86	1.28	4.14	5	.0
September--	78.6	52.3	65.5	95	31	765	2.86	1.20	4.19	6	.0
October----	67.8	41.0	54.4	88	18	446	2.35	1.15	3.32	5	.0
November---	52.1	31.3	41.7	77	6	121	3.05	1.68	4.16	6	2.0
December---	40.9	23.0	32.0	67	-10	62	2.90	1.04	4.37	5	3.1
Yearly:											
Average--	63.5	40.5	52.0	---	---	---	---	---	---	---	---
Extreme--	---	---	---	99	-19	---	---	---	---	---	---
Total----	---	---	---	---	---	5,595	39.88	34.04	45.82	75	16.6

* A growing degree day is a unit of heat available for plant growth. It can be calculated by adding the maximum and minimum daily temperatures, dividing the sum by 2, and subtracting the temperature below which growth is minimal for the principal crops in the area (40° F).

SOIL SURVEY OF RIPLEY COUNTY
AND PART OF JENNINGS COUNTY, INDIANA
1981

Figure 3



Route of
State Highway 129

1.3 - NATURE OF THE PROBLEM:

Since its construction in 1963, the condition of Bischoff Reservoir has deteriorated. Primary sources of pollution are urban infrastructure and land use and agricultural activities. Figure 3 on page 10 identifies potential sources of pollution and their location.

URBAN INFRASTRUCTURE AND LAND USE:

Existing developments in and around the town of Morris are serviced by septic systems. These systems are located in soils that have very high water tables, and therefore have the tendency to overflow and sheet flow in the upper reaches of the reservoir.

Housing developments currently being constructed in the northern branch of the reservoir are contributing significant amounts of sediment to the waterbody during construction activities. In particular, storm water carrying sediment from the Hillendale Development is contributing sediment to Bischoff Reservoir. The Ripley County Conservation District staff reviewed and approved an erosion control plan for the Hillendale development. However, it appears that the erosion control plan has not been fully implemented by the developer. Increased enforcement of the erosion control plan and improved communication among the developer and subcontractor about features of the plan may help to control erosion problems. Construction of State Highway 129 also caused erosion. Once constructed, State Highway 129 further aggravated erosion problems in the northern portion of the reservoir, since three major ditches from 129 drain directly into the corner/inlet of the reservoir. Figure 8 on page 22 shows the location of these ditches. These ditches contribute to the transport of soil and other runoff into the reservoir.

AGRICULTURAL ACTIVITIES:

Aerial photos reveal that a large number of farming operations have a tiled drainage system. The discharge from the tile system allows fertilizers and pesticides to be easily transported to the runoff swales that feed into Bischoff Reservoir. In addition, the three feedlots (ten acres and larger) have been seriously depleted of vegetation, which further contributes to erosion. Also, waste from livestock on these feedlots flows into the watershed and decreases water quality. The location of these feedlots and the points at which livestock have access to inlet streams are represented by point C on Figure 8.

Agricultural activities also contribute significantly to sedimentation problems. Excessive soil erosion occurs on sloping cropland and row cropped fields.

Local residents report that algal blooms interfere with boating and fishing. Algal blooms become entangled in boat motors, and disrupt fish populations. On-site investigations, conversations with the Batesville Water Utility Engineer, and Indiana State Board of Health Guidelines indicate that swimming in Bischoff Reservoir could pose a health hazard.

The consequence of all of the above factors is that Bischoff Reservoir appears to be in the most extreme stage of eutrophication. Massive blooms of the blue-green algae have become common during the growing season. And, according to the Batesville Water Utility Engineer, Secchi disk transparency has declined to approximately one foot (from 2.5 feet in the mid-seventies) during peak growing seasons.

The receiving stream, Bobs Creek, undoubtedly suffers significant impairments as a result of the elevated nutrient and algae concentrations being discharged into it from Bischoff Reservoir. Mollenkramer Reservoir, another water supply reservoir downstream on Bobs Creek, is not used for water supply by the Batesville Water and Gas Company at this time.

SECTION II - DATA COLLECTION

This section presents the data compiled for this investigation, including water depths, water quality, sediment composition, land use, and zoning. Data was collected on physical, biological, and chemical characteristics of Bischoff Reservoir.

2.1 - HISTORICAL DATA:

Bischoff Reservoir has been the subject of numerous investigations over the last twenty-seven years. The Indiana Department of Natural Resources (IDNR), the Indiana Department of Environmental Management (IDEM), and the Indiana State Board of Health (ISBH), have all evaluated Bischoff Reservoir.

IDNR INVESTIGATIONS:

The IDNR conducted a hydrogeographic survey of the reservoir in 1962 and a fisheries survey in 1963. Other investigations by the IDNR included a 1966 evaluation of fishery survey methods; a 1965 and 1966 creel survey; a 1966 determination of reservoir standing crop; a 1967 restocking of the reservoir (after it was drained by the City of Batesville); a 1970 fisheries survey; and a five year (1973-1977) research project. In 1984, the IDNR produced a "Fish Management Report on Bischoff Reservoir". In this report the IDNR developed a temperature-depth relationship near the dam and evaluated aquatic conditions. The IDNR also measured the transparency (4 feet, 6 inches); and evaluated the color of the water (greenish). The 1984 report further determined that dissolved oxygen in the main reservoir, at approximately 15 feet to the bottom of the reservoir, was extremely low. And, the IDNR found that total alkalinity increased by approximately 40% from the surface to the bottom, while the pH changed from 9.3 to 7.3 at the bottom.

The 1984 report also noted the expansion of pondweeds (_Potamogeton_ sp.), water milfoil (_Myriophyllum_ sp.), and cattails in the shallow waters: water up to two feet deep has nearly a 50% coverage by cattails (_Typha_ sp.), and 20 to 100 feet from shore, filamentous algae cover about 25% of the reservoir's bottom. Finally, in 1987, the IDNR Division of Water, Surveying Section, initiated a new hydrogeographic evaluation and found no significant changes from previous evaluations.

ISBH AND IDEM INVESTIGATIONS:

In the mid-seventies, the IDEM conducted a comprehensive survey of Indiana lakes, to include Bischoff Reservoir. The IDEM's results were reported in the ISBH's 1984 report entitled "Indiana Public Water Supply Systems" and in the IDEM's 1986 report entitled "Indiana Lake Classification System and Management Plan". The ISBH report analyzed water quality with respect to its use as a water supply, while the 1986 report focused on the overall ecological health of Indiana lakes.

The Indiana Department of Environmental Management (IDEM) has long been aware of the water quality problems in Bischoff Reservoir. With respect to its trophic status, Bischoff is a Class Two (intermediate quality intermediate level eutrophic stage) reservoir. This classification was based, in part, on the presence of a total phosphorus concentration of 0.12 milligrams per liter (mg/L), and a Secchi disk transparency of 2.5 feet.

The IDEM calculated an Eutrophication Index (EI) value of 63, on a scale of 0 to 75. The EI value of 63 was calculated based on data collected in the mid-1970's. During the course of this study an EI value of 47 was determined, which means that Bischoff meets the criteria of a Class Two Trophic Status reservoir. Table 2 describes characteristics of lakes falling between 26 and 50 (Class Two) on the Eutrophication Index. Table 3 describes morphometric and trophic characteristics of lakes in Class Three. Until the IDEM officially reassigns Bischoff Reservoir to a Class Two Status, it should be considered a Class Three reservoir. Table 3 also describes characteristics of lakes falling into a VII-B management group.

For management purposes, the IDEM classified the reservoir as a Group VII-B lake. (See the 1986 "Indiana Lake Classification System and Management Plan.") Table 4 shows Bischoff Reservoir grouped with other Class VII-B lakes. The Class VII-B lake management group is designated for those lakes having areas from 28 to 551 acres with mean depths of 12.2 feet to 19.6 feet and eutrophication indexes ranging from 27 to 54 (see Table 5). The water quality problems of Group VII lakes are not severe enough to warrant drastic restoration procedures, so priority is given to reducing nutrient inputs. However, in some cases selected restoration techniques may be advisable for Group VII lakes.

The 1984 ISBH report noted that raw water from Bischoff Reservoir was first pumped into the Liberty Park Reservoir and from there into the treatment plant. While the water in Liberty Park Reservoir had a chance to settle out, the intake water into the treatment plant had developed various chemical characteristics as shown on Table 6, "Data on Indiana Public Water Supplies". These characteristics were hardness, and calcium, magnesium, sodium, potassium, iron, manganese alkalinity, chlorides, sulfates, phosphates, nitrates, and fluorides. The phosphates of the raw water usually range from .10 to .20 milligrams per liter. This is compatible with present day measurements that are found within Bischoff Reservoir.

TABLE 2

EVALUATION OF TROPHIC CLASS

Class Two. Intermediate Quality, Intermediate Level Eutrophic Lakes. (26-50 Eutrophy Points)*

Class Two lakes are usually productive and very slowly moving toward senescence. They are impacted by the activities of people, but trophic changes are usually subtle. In the absence of a chemical control program, they frequently support extensive concentrations of macrophytes and/or algae, but seldom to the extent that one or more attainable lake uses are significantly impaired. Class Two includes the majority of Indiana's natural lakes.

Class Two lakes commonly exhibit the following characteristics:

1. Total P concentrations of 0.04 to 0.06 mg/l as a water column average.

2. TKN values of 0.6 to 0.9 mg/l as a water column average.

3. Dissolved oxygen values are usually at 0.0 mg/l in the deeper waters of the hypolimnion during stratification.

4. Plankton blooms occur frequently during hot weather but these are not commonly of nuissance proportions. Blue-green species are commonly dominant, but often alternate with diatoms.

5. There are usually extensive, but non-problem, macrophyte concentrations in bays and littoral areas. Man-made channels and boat lanes usually have some degree of problems with the overproduction of macrophytes and/or algae.

6. Solar light values at a depth of three feet usually range from 30 to 50% of surface value.

* This table was taken from the Indiana Lake Classification System and Management Plan, Indiana Department of Environmental Management, 1986.

Table 3

BISCHOFF RESERVOIR
MORPHOMETRIC & TROPHIC CHARACTERISTICS

Lake Name	Trophic Class	Size (Acres)	Maximum Depth (ft)	Mean Depth	Total Phosphorus (mg/l)	Secchi Disc (ft)	Eutrophication Index	Lake Management Group
Ripley Co.								
Bischoff	Three	200	27.0	15.0	0.12	2.5	63	VII B
Feller	Three	6	8.0	4.0	0.28	3.0	64	IV A
Hahn	Two	8	12.0	6.0	0.04	5.0	46	VII A
Liberty Park	Two	11	18.0	7.0	0.06	5.0	26	VI A
Mollenkramer	Three	93	10.0	5.0	0.10	4.0	59	V
Oser	Two	12	18.0	9.0	0.16	5.0	34	VII A
Versailles (1975)	Three	230	20.0	5.0	0.11	1.5	52	VII A
Versailles (1985)	Two	--	--	--	0.13	2.0	30(Atypical)	--

Class Three lakes and reservoirs are those that are the most productive and have the lowest water quality. They are considered eutrophic or in some cases hypereutrophic. Without chemical control programs many of these waterbodies would support extensive weed and/or algal growth during the summer months. Swimming, boating and fishing may be impaired occasionally but seldom precluded. Nuisance blooms of blue-green algae commonly occur in Class Three lakes and reservoirs and may persist for much of the warm weather months. In the most highly productive of these water bodies, dissolved oxygen depletion may cause fish kills during extended periods of hot weather or winter kills during periods of ice and snow cover. Waterbodies that are presently receiving direct wastewater discharges or those that have received such discharges in the past generally belong to this class. There are 64 natural lakes (6,147 acres) and 43 impoundments (2,407 acres) included in Class Three.

INDIANA 305(b) REPORT, 1986-1987,
Indiana Department Of Environmental Management
Office Of Water Management

Table 4

GROUPING OF INDIANA LAKES BY CLUSTER ANALYSIS

ID#	Lake	Size (Acres)	Mean Depth	Index
Group VII Subgroup B				
38.	Fletcher	45.0	19.6	46
452.	Old	32.0	19.4	48
120.	Emma	42.0	16.7	44
318.	Tamarack	50.0	17.6	42
59.	Caldwell	45.0	17.8	46
243.	Bear	32.0	12.2	54
231.	Gordy	31.0	21.9	43
64.	Dewart (SE. Basin)	551.0	16.3	36
65.	Dewart (SW. Basin)	551.0	16.3	36
66.	Dewart (NW. Basin)	551.0	16.3	36
303.	Big Turkey	450.0	16.2	44
187.	Lake of the Woods	416.0	16.4	42
195.	Boggs Creek	600.0	12.5	45
62.	Center	120.0	17.2	31
145.	Pigeon	61.0	19.0	27
328.	Pleasant (St. Joseph)	29.0	18.0	29
262.	Gilbert	28.0	17.5	28
237.	Millers	28.0	14.6	35
265.	Long (Chain O'Lakes)	40.0	15.8	33
249.	Long (At Laketon)	48.0	16.0	30
287.	Barton	94.0	14.3	32
216.	Dixon	33.0	14.5	30
215.	Cook	93.0	17.7	40
254.	Bixler	120.0	17.4	38
245.	Cree	58.0	15.7	39
373.	West Otter	118.0	16.6	35
	Upper Summit	6.0	15.0	42
	Carr	79.0	17.0	50
	Little Barbee	74.0	13.0	56
	McClures	32.0	12.8	51
	Ridinger	136.0	21.0	58
	Rainbow	16.0	15.6	31
	Bowen	30.0	15.0	41
	Crane	28.0	12.9	45
	Dock	16.0	16.6	38
	Harper	11.0	14.5	60
	High	123.0	10.1	53
	Rivir	24.0	15.8	38
	Eliza	45.0	15.0	42
	Bischoff	200.0	15.0	63
	Black	18.0	15.0	36

Table 5

A SUMMARY OF THE LAKE GROUPINGS FROM CLUSTER ANALYSIS

	Area (acres)	Mean Depth (feet)	Index
Group I	3,060-3,180	17.5-22.0	16-20
Group II			
A	50-48	17.5-31.0	1-16
B	40-1,034	31.2-45.0	3-25
C	37-388	32.7-40.5	18-41
Group III	1,291-1,864	5.0-24.5	23-48
Group IV			
A	26-385	2.0-7.3	50-65
B	25-326	7.9-20.0	50-75
C	150-575	5.0-14.0	62-75
D	31-562	21.0-31.1	46-67
Group V	30-414	5.5-15.7	2-18
Group VI			
A	25-421	15.0-27.0	13-39
B	228-282	24.7-26.9	38-39
C	802	20.7	31
Group VII			
A	25-828	5.0-13.2	18-37
B	28-551	12.2-19.6	27-54
C	25-424	5.5-14.4	33-46

PAGE 54-INDIANA LAKE CLASSIFICATION SYSTEM AND MANAGEMENT PLAN
Indiana Dept. of Environmental Management, 1986

OTHER DATA:

In 1963, the United States Geological Survey (USGS) and IDNR generated a bathymetric map (see sheet 1 in Appendix B). This map showed bottom contours to a depth of 27 feet, which is equivalent to 1920 acre feet. In 1984, the IDNR's Survey Section reexamined Bischoff Reservoir. The IDNR examination revealed that the average depth in the reservoir had decreased by 1.6 feet since 1963, indicating the addition of approximately 320 acre feet of siltation. Conversations with representatives of the IDNR revealed that because the depth had decreased by only 1.6 feet, the 1963 bathymetric map was not modified.

Storage-depth curves (See Figure 4) were generated based on the 1963 USGS-IDNR data and the consultant's 1989 estimates of depth to bottom. According to these storage-depth curves, present day siltation appears to be about 379 acre feet. It appears that the erosion of the watershed into Bischoff Reservoir (in the form of siltation) is proceeding at the rate of ten to eleven tons per acre per year, which is over twice the acceptable level of five tons per acre per year.

The U.S. Soil Conservation Service (SCS) developed a soils map for Ripley County in 1988. While the exact percentage of erodible soils in the watershed is not known, the water draining into Bischoff Reservoir runs over several highly erodible soil types. Approximately 13% of the soils in the watershed can be considered highly erodible. Figure 5 shows the soil types identified by the SCS as highly erodible.

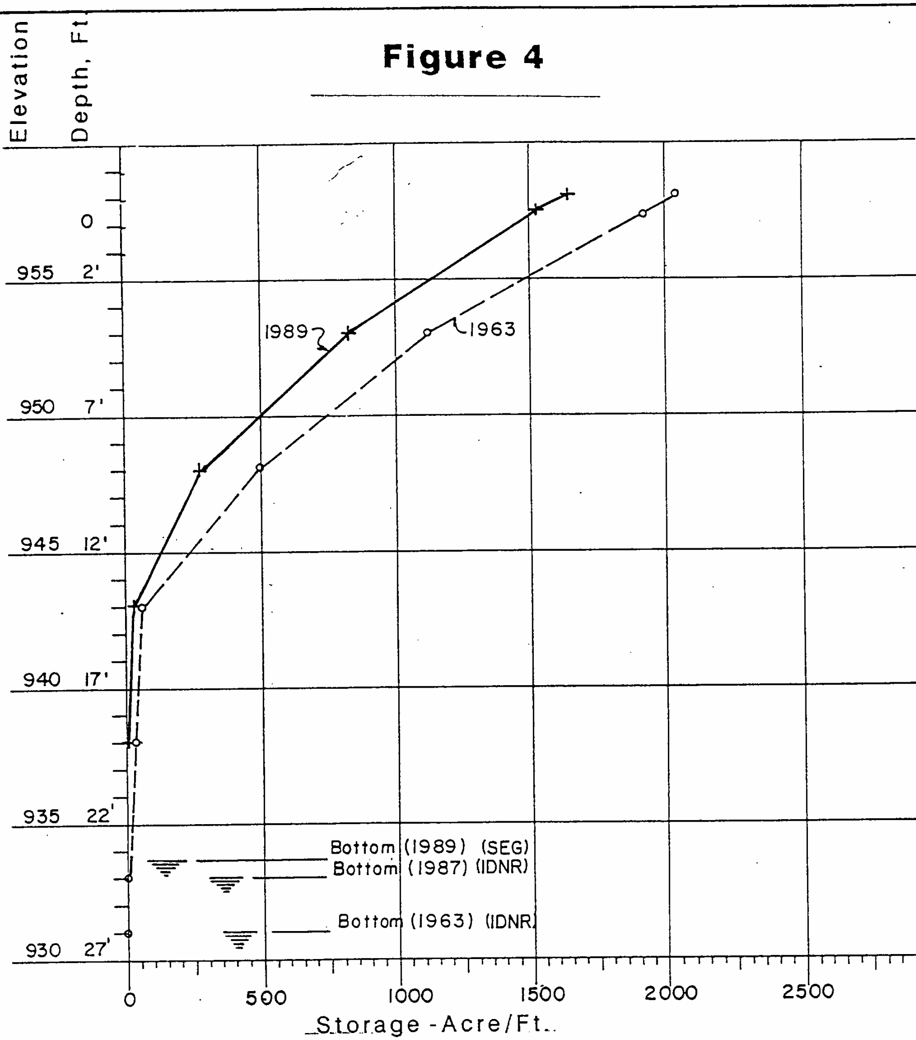
2.2 - CURRENT DATA COLLECTION:

Data was collected from a variety of sources, including previous reports, interviews with specialists and local officials, and field tests. Field tests were performed on a number of physical, biological, and chemical parameters. The majority of these tests were performed based on methods outlined in the 1988 IDEM Field and Laboratory Procedures Manual. All water quality sampling was performed in accordance with procedures specified in a January 1988 letter from IDEM to the IDNR, Division of Soil Conservation. See Appendix A for a copy of this letter.

LAND USE:

Land use and zoning information in the Bischoff Reservoir watershed was collected from several sources. The city of Batesville provided a large copy of an aerial photograph of the reservoir and a portion of the watershed, as well as a zoning map. The entire Bischoff Reservoir watershed area is outlined on Figure 6. See Figure 2 on page 5 for zoning information. The remainder of the zoning map was compiled from information provided by the Ripley County Plan Development Commission in Versailles, Indiana. From this information, the Consultant determined the proportion of land in agricultural, woodland, and residential type land uses. (See Figure 7 for a comparative land use chart.)

Figure 4



STORAGE DEPTH (Acre/Ft.)
BISCHOFF RESERVOIR

SOURCE:
SEG ENGINEERS & CONSULTANTS(SEG)
INDIANA DEPARTMENT OF NATURAL RESOURCES (IDNR)

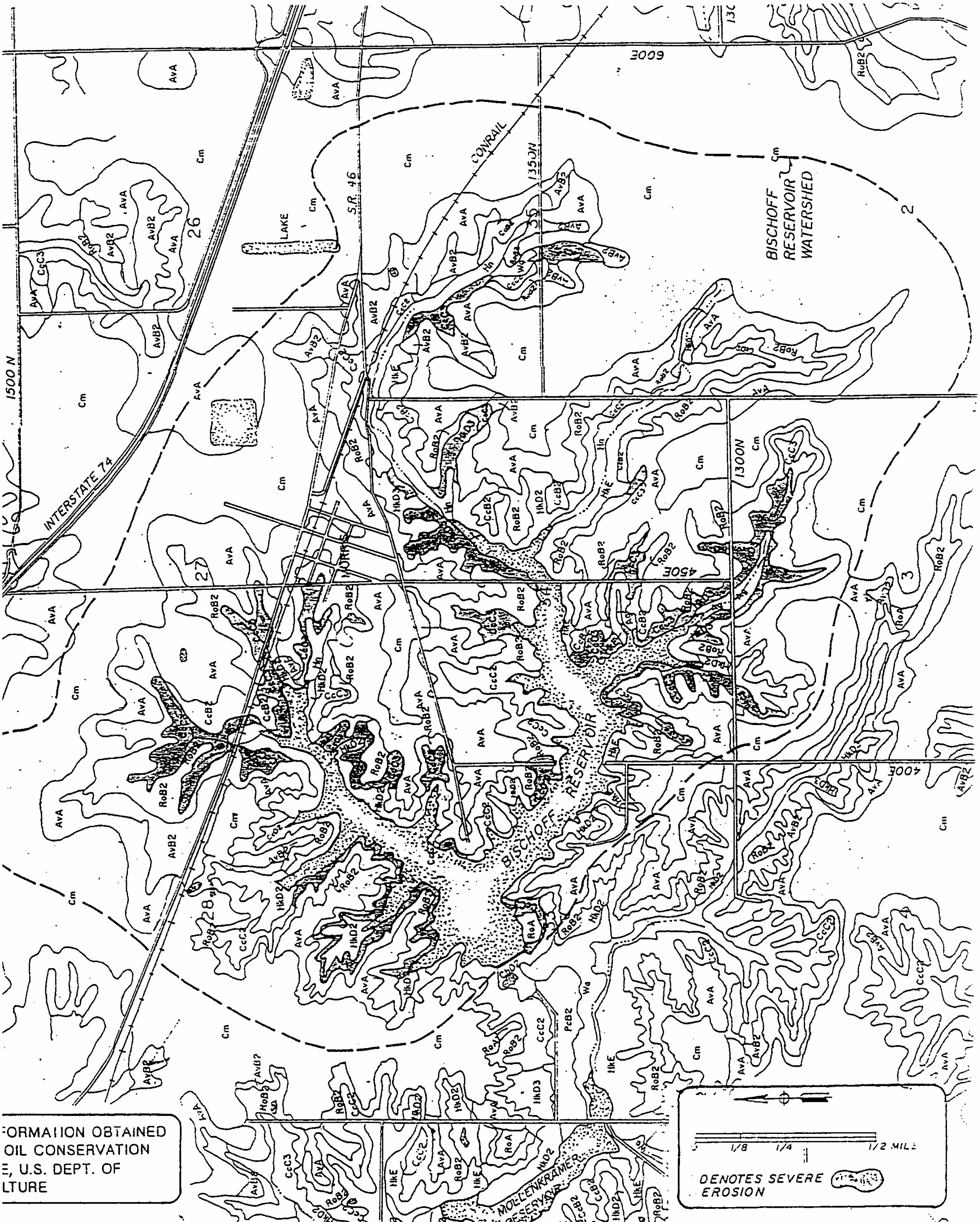
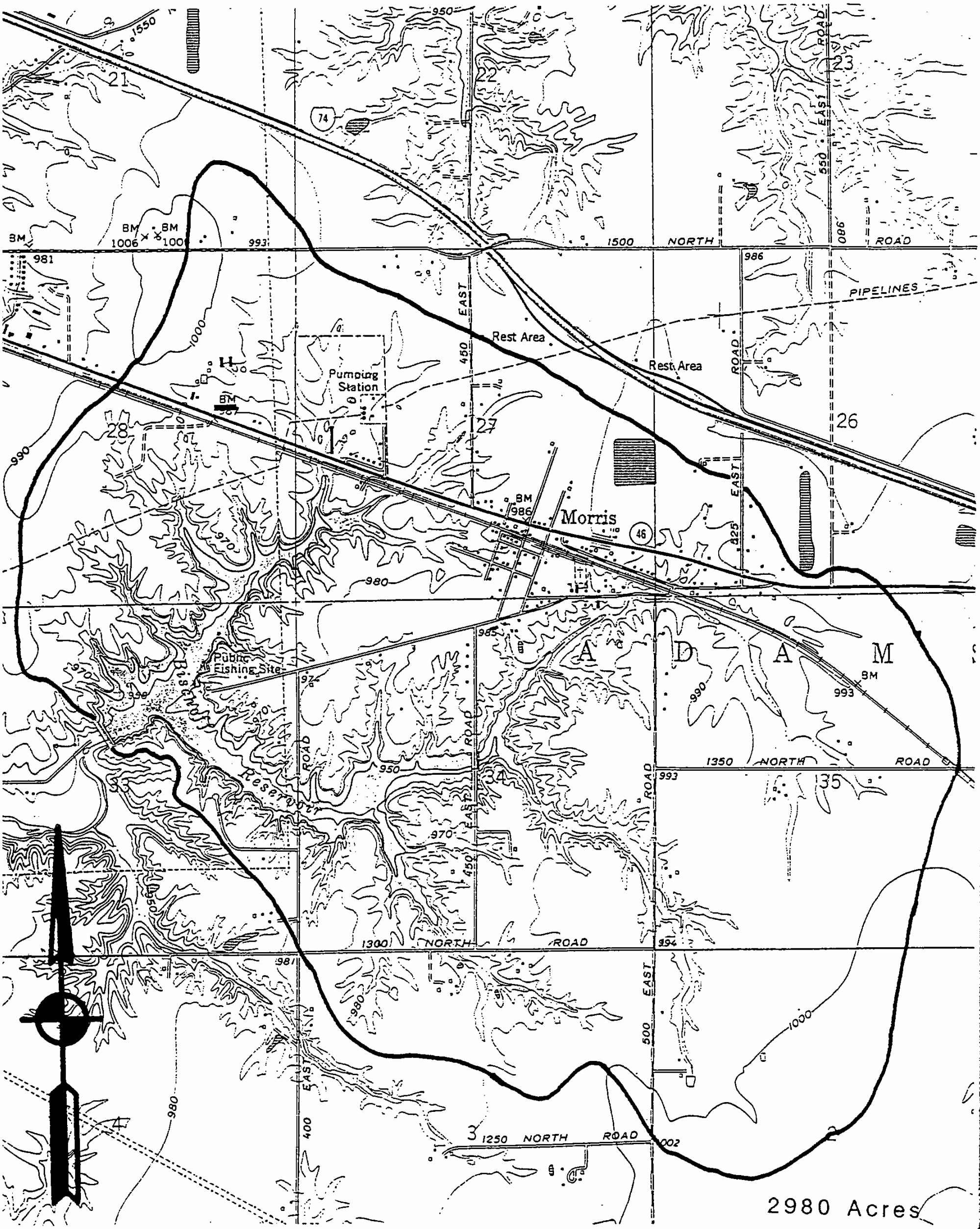


Figure 5

SEVERE SOIL EROSION AREAS-
BISCHOFF RESERVOIR WATERSHED

Figure 6

BISCHOFF RESERVOIR WATERSHED AREA



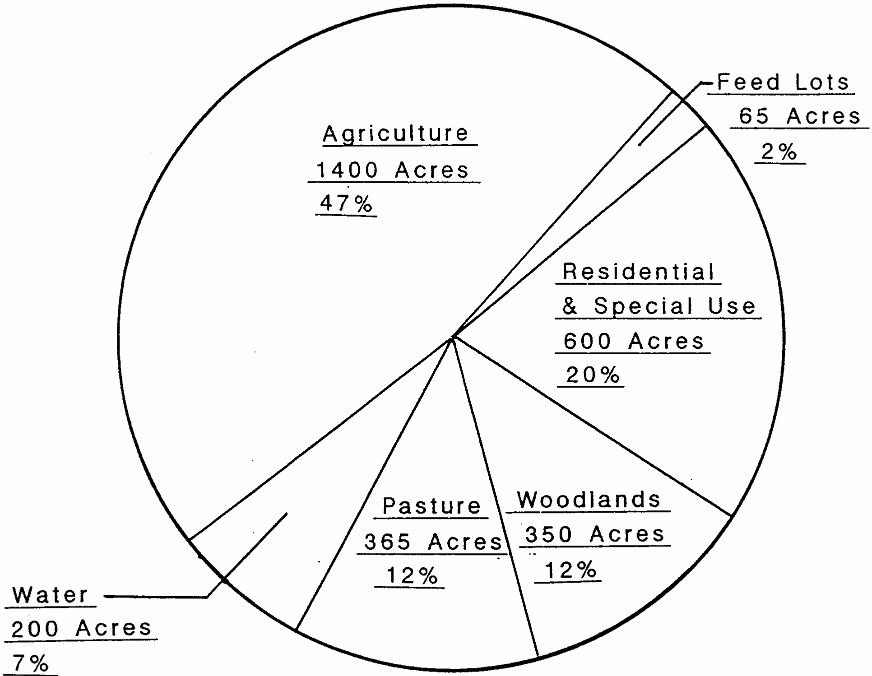


Figure 7

COMPARATIVE LAND USE CHART-
BISCHOFF RESERVOIR WATERSHED

Total 2980 Acres

The land use pie chart produced for this study shows the extent of agricultural development and other land uses within the Bischoff Reservoir Watershed. Fourteen Hundred (1400) acres, or 46.98% of the land in the watershed is agricultural crop land. Six hundred acres (600) or 20.13%, is in industrial or residential use, and 365 acres (12.25%) is pasture land. There are approximately 350 acres (11.75%) of woodland; 65 acres (2.18%) are devoted to feedlots; and 6.17% of the watershed is comprised of water or wetlands.

A visual reconnaissance of the watershed was also conducted on August 18, 1989 to verify locations of several large feedlots, pipeline crossings, large residential areas, grain and fertilizer elevators, oil storage facilities, and large truck terminals. Figure 8, Potential Sources of Pollution, shows the locations of these facilities.

The watershed reconnaissance identified several of the specific features and activities that represent possible sources of nutrient loading to Bischoff Reservoir. Located in undesirable soils (with respect to permeability), the town of Morris' septic tanks are the most direct source of fecal coliform runoff. (See Figure 8.) There are approximately eighty residences within Morris, which is a relatively high density of residential development relying solely on septic systems. Within the remaining watershed, small acreage farms representing an additional fifty homes also depend on septic fields for disposal of waste.

Three major feedlots and a variety of animal lots within the watershed may contribute some of the nutrients, with the rest most likely coming from the agricultural use of fertilizers, herbicides, and pesticides.

The livestock feedlots have some degree of cover for the animals but most of them are open lots and feeding areas. Any accumulation of manure on the area is applied to the fields which adds to the nutrient loading. Runoff from these feedlot facilities discharges directly into the waterways that lead to Bischoff Reservoir. Figure 8 shows the location of these feedlots and points where livestock have access to the reservoir.

Agricultural activities are thought to contribute significantly to sedimentation into Bischoff Reservoir. A representative of the Ripley County Soil and Water Conservation District (SWCD) reports that maximum tillage programs increase soil erosion from water and off-site sedimentation. Excessive soil erosion is also a problem on sloping cropland soils in the watershed. The SWCD also reports that on an annual basis steeply sloping soil may be losing up to 50 tons of soil per acre due to sheet erosion, and 10-13 tons per acre from sheet and rill erosion on intensively cropped land. Additional erosion occurs from gullies present on continuously row-cropped fields.

Overland flow from the fertilizer (sales and handling) plant in Morris drains to the adjacent drainage way which eventually becomes stormwater runoff.

2.3 FIELD SAMPLING METHODS

BATHYMETRY:

A bathymetric survey was conducted in August 1989 on a portion of Bischoff Reservoir using sounding methods and measuring tape operated from a survey boat. Soundings were taken in the vicinity of the dam. A survey grid was established from the dam face upstream for 500 feet and placed on approximately 100 foot grids to determine the depth to the bottom. This data (Sheet 2 in Appendix B) was used to estimate bottom contours for the rest of the reservoir. The resulting estimates provide a general overview of the condition in the reservoir.

WATER QUALITY:

In-reservoir water quality samples were taken on August 30, 1989. All analyses except pH, conductivity, and temperature were conducted off-site on August 31, 1989. In-reservoir profile measurements of dissolved oxygen were made in the laboratory via the Winkler Titration method. Secchi disk depth and total water depth were also recorded at each of the sampling sites. Figure 9 shows the location of the three sampling sites: site "A" is near the dam; site B is on the north finger, and site C is on the south finger of the reservoir.

In-reservoir water quality parameters were measured at the three sample sites. Water and sediment quality parameters are listed in Table 7. Sediment samples were not taken at sampling site A. Appendix A contains additional water and sediment quality data.

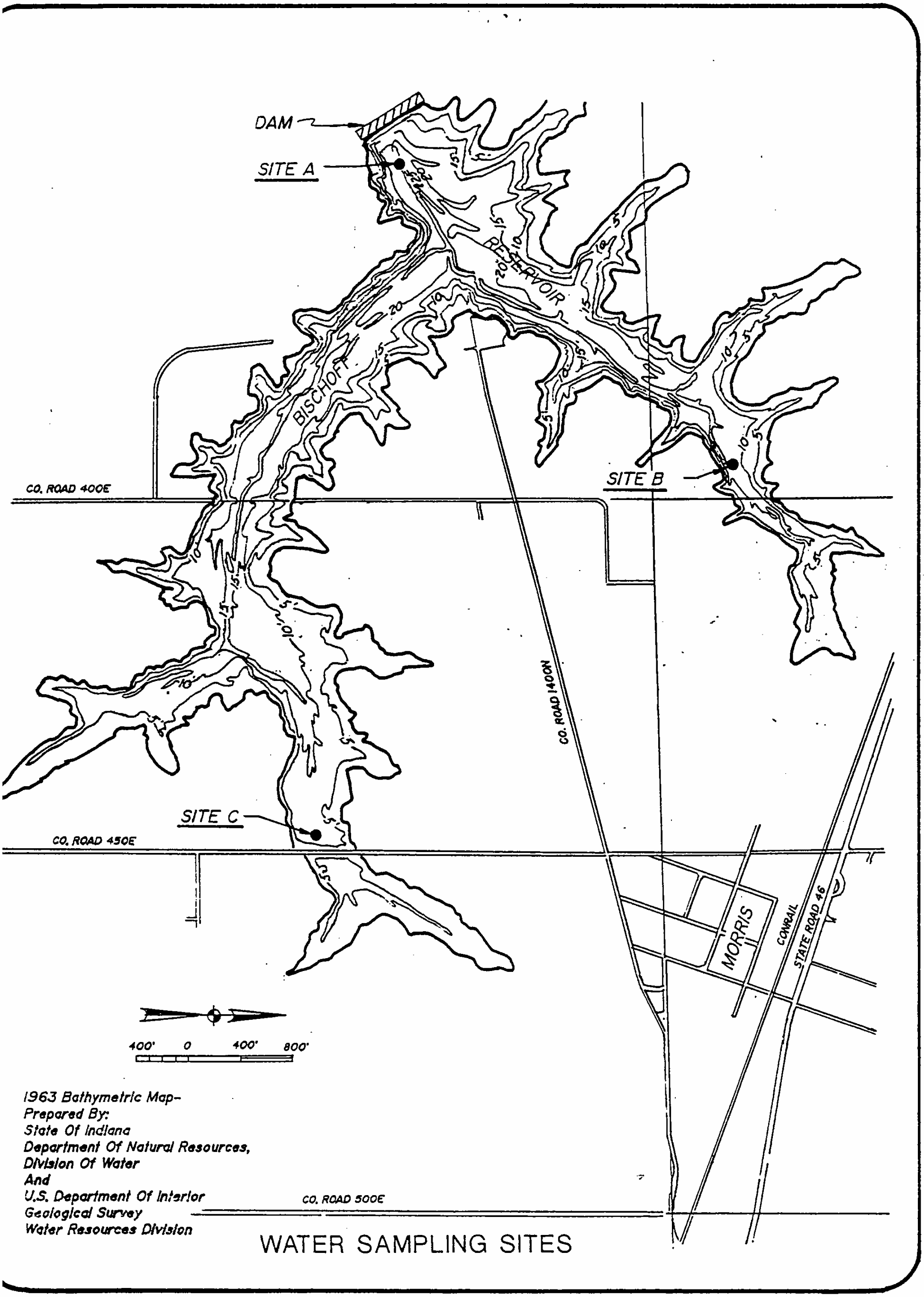
Water samples were collected at the surface and at five foot intervals at each of the sampling sites. Water samples were taken at site A at more frequent intervals. All samples were received at the laboratory within 48 hours of collection.

Plankton was sampled using an 80 micron plankton net. A tow was made through the thermocline or the euphotic zone, whichever was applicable at each site. The samples were collected on the surface and preserved in a dark bottle with Lugol's solution. The samples were then analyzed using a Sedgewick-Rafter cell and Whipple grid to count both diatoms and non-diatoms.

Sediment samples were collected in the field using an Eckman dredge. The samples were collected at the surface of the dredge sample with a sterile glass jar, labeled, kept cool, and analyzed in the laboratory.

The light transmission at 3 feet was assumed to be roughly 14%. The parameter was developed using Robert G. Wetzel's methodology for calculating light transmission, described in the text <u>Limnology</u>.

Figure 9



WATER SAMPLING SITES

TABLE 7

PARAMETERS

pH	Mercury
Acidity	Nitrate-N
Ammonia-N	Oil & Grease
Antimony	Non-Filterable Residue
Arsenic	Selenium
Beryllium	Silver
Cadmium	Specific Conductance
Chromium	Temperature
Cobalt	Thallium
Copper	Zinc
Cyanide (Total)	Fecal Coliform Bacteria
Dissolved Oxygen	Phosphorus (Total)
Iron	Phosphorus (Soluble)
Kjeldahl Nitrogen	Phenols
Lead	Pesticides/PCB's
Manganese	

Conductivity, temperature, and pH were measured with a Cambridge Scientific Instruments Conductivity, Temperature, and pH meter. The instrument was calibrated for pH with buffer solutions of pH 7.0 and 10.0 at each sampling station, with the appropriate temperature set on the instrument. Temperature was checked against the etched-stemmed, filled glass thermometer on two occasions to make sure the instrument was reading properly. Conductivity was calibrated using a standard solution with temperature set at the appropriate level.

Dissolved oxygen samples were collected with the Kemmerer sampler and placed in winkler bottles. One ml of both managanous sulfate ($MnSO_4$) and alkali-iodide-azide solutions were added to each sample. Once the flocculant settled out, 1 ml of sulfuric acid was added to preserve the sample. The sample was then titrated to an end point with the appropriate reagents.

Ammonia, nitrate-N, total phosphorus, and dissolved phosphorus were analyzed using methods found in Standard Methods for the Examination of Water and Wastewater, 1985. These parameters were placed in 500 ml bottles and preserved in the field using sulfuric acid (H_2SO_4). Ammonia was analyzed using Method 417-E Ammonia, Selective Electrode Method. Nitrate-N was analyzed using the Automated Cadmium Reduction Method-418F. Total phosphorus was analyzed using two steps: digestion (424C) and the Ascorbic Acid Method (424). Dissolved phosphorus was analyzed using three steps: digestion (424C), Ascorbic Acid Method (424F), and a filtration method (441).

Total Kjeldahl Nitrogen was determined by the Potentiometric, Ion Selective Electrode Method (# 351.4) from U.S. Environmental Protection Agency 1979 standards.

2.4 - FIELD SAMPLING RESULTS:

WATER QUALITY:

Water clarity was relatively low with a secchi disk registering 2 feet - 6 inches at sample sites A, B, and C. Water quality data for all three sampling sites is presented on Table 8 for comparison. Figures 10, 11, and 12 show depth vs temperature/conductivity/pH for each individual sampling site. Figure 12 shows depth vs. temperature/conductivity vs pH for all three sites. Figure 13 shows depth vs dissolved oxygen and temperature for all three sites; Figure 14 shows nutrient data vs. depth; Figure 15 shows nutrient data vs. ammonia; and Figure 16 shows depth vs. total phosphorus. Note that at greater depths, nutrient concentration generally increases.

TABLE 8

WATER QUALITY DATA

	pH	Ammonia-N mg/L	Nitrate-N mg/L	Total Phosphorus	Dissolved Phosphorus	Conduct.	Fecal Coliform	TKN	TSS.	Temp.	D.O.
Site A											
A-Surface	9.4	---	---	---	---	290	>200	---	---	82.4	11.8
A-5'	7.38	0.05	<0.10	0.040	0.004	248	---	1.5	18	78.4	4.50
A-10'	7.14	0.17	<0.10	0.050	0.004	251	---	1.5	12	77.2	1.10
A-15'	7.45	0.72	<0.10	0.040	0.007	269	---	1.8	20	72.4	1.05
A-20'	6.43	4.2 *	<0.10	0.380	0.380	294	---	3.6*	40	69.2	1.0
A-1' from bottom (22')	6.98	5.5 *	<0.10	0.020	0.010	287	---	5.0*	50	64.5	1.0
Total Depth 22.5'											
Site B											
B-Surface	7.94	0.05	<0.10	0.010	<0.002	231	>200	1.4	6	82.2	11.4
B-5'	7.66	0.05	<0.10	0.020	0.006	226	---	1.4	14	78.0	11.4
B-10'	7.50	0.14	<0.10	0.060	0.010	227	---	1.4	9	76.9	2.12
Total Depth 10.5'											
Site C											
C-Surface	---	<0.05	<0.10	0.049	<0.002	231	>200	.79	43	83.5	10.40
C-5'	7.91	<0.05	<0.10	0.010	0.010	226	---	1.4	12	79.5	9.34
C-8'1" off bottom	---	<0.09	<0.10	0.060	0.020	227	---	.75	44	78.3	7.13
Total Depth 9'											

* Due to the inherent source of error associated with analytical procedures, the ammonia values appear to be higher than the TKN values. This is chemically impossible. The margin of error for ammonia values is +/- 20%. These values have not been used in calculation of the EI score.

Figure 10

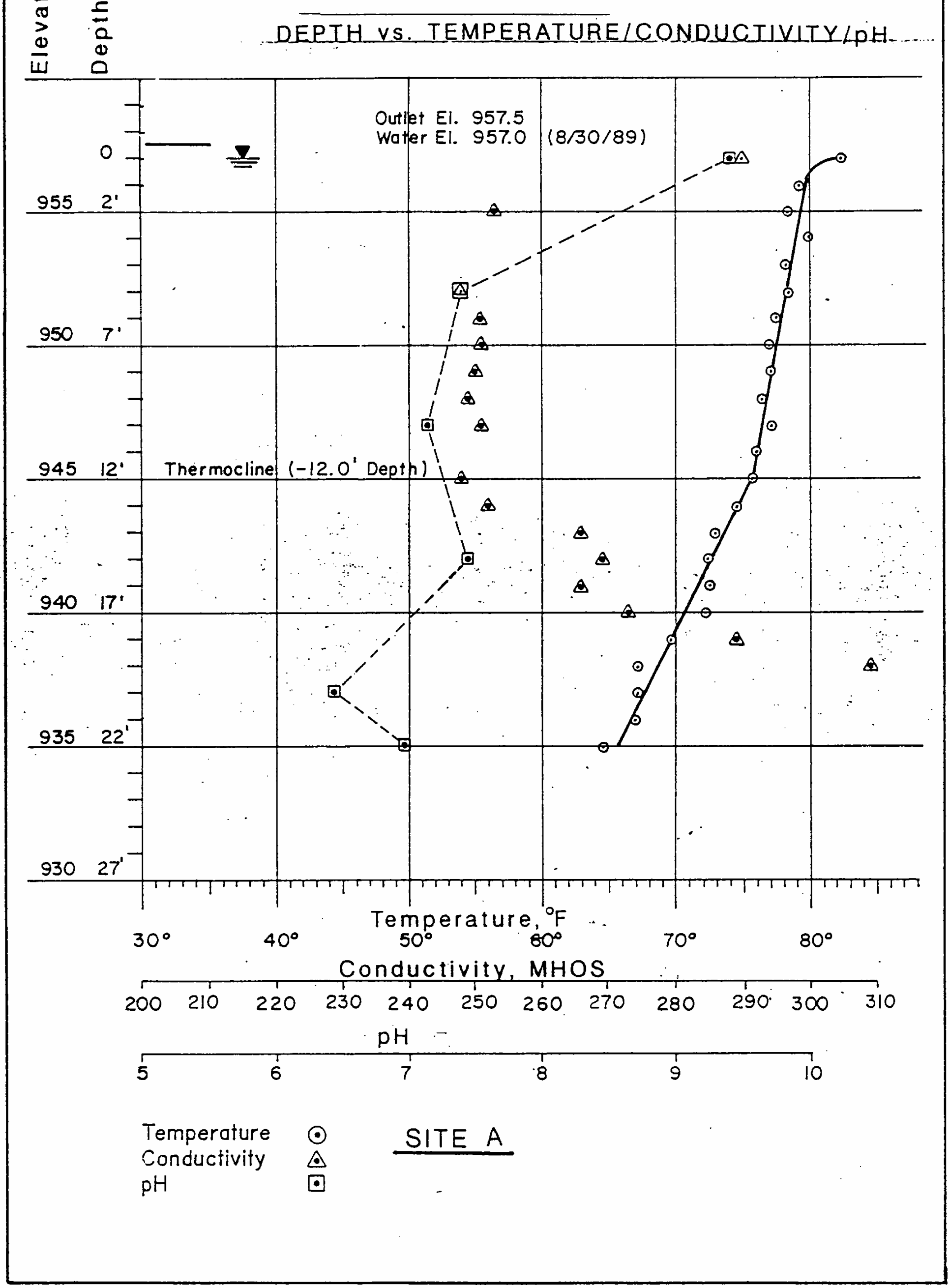
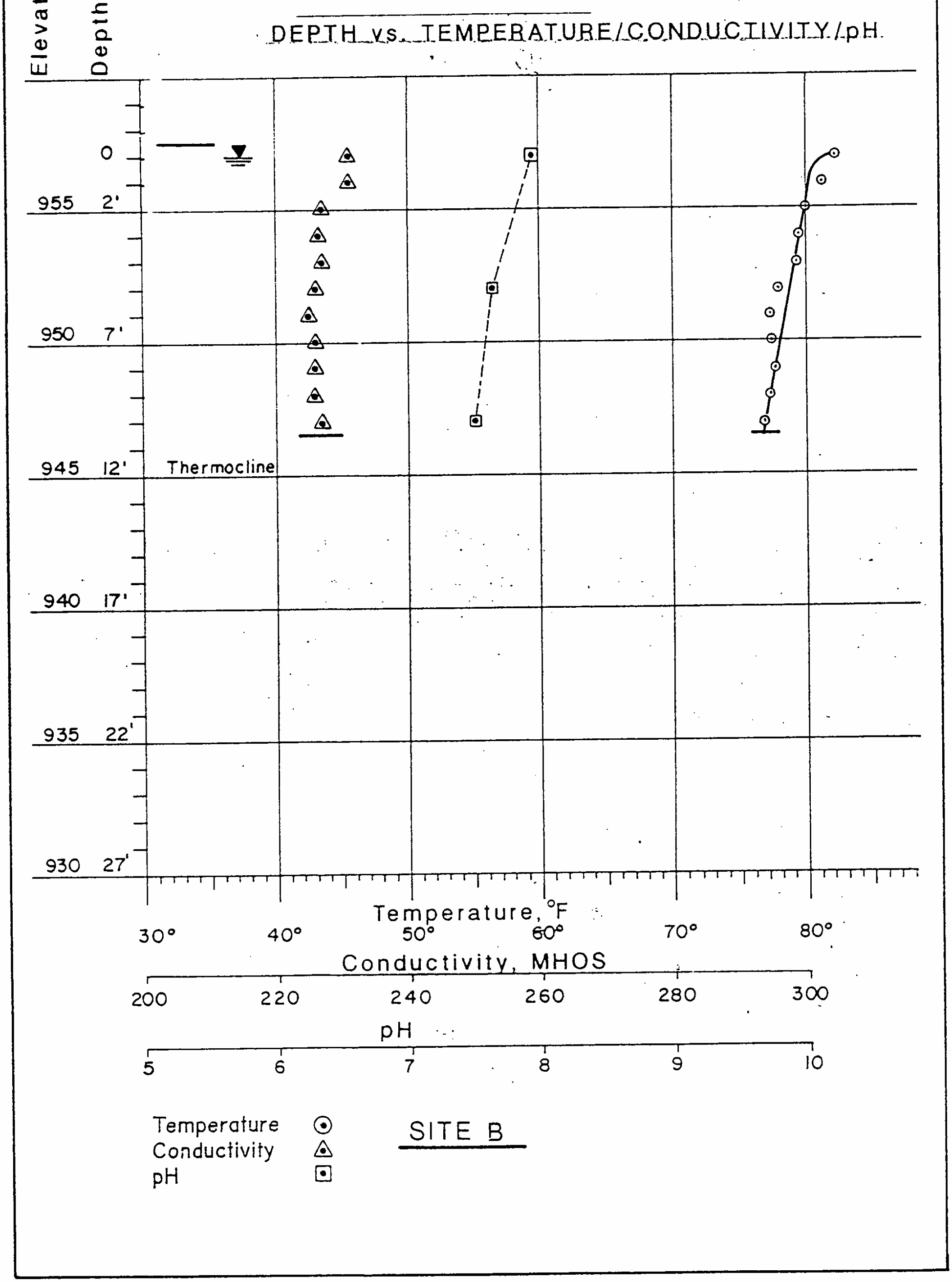

DEPTH vs. TEMPERATURE/CONDUCTIVITY/pH
Elevation
Depth, Ft.
Outlet El. 957.5
Water El. 957.0 (8/30/89)
0
955 2'
950 7'
945 12'
Thermocline (-12.0' Depth)
940 17'
935 22'
930 27'
Temperature, °F
30° 40° 50° 60° 70° 80°
Conductivity, MHOS
200 210 220 230 240 250 260 270 280 290 300 310
pH
5 6 7 8 9 10
Temperature
Conductivity
pH
SITE A

Figure 11


DEPTH vs. TEMPERATURE/CONDUCTIVITY/pH
Elevation
Depth, Ft
0
955 2'
950 7'
945 12'
940 17'
935 22'
930 27'
Thermocline
Temperature, °F
30° 40° 50° 60° 70° 80°
Conductivity, MHOS
200 220 240 260 280 300
pH
5 6 7 8 9 10
Temperature
Conductivity
pH
SITE B

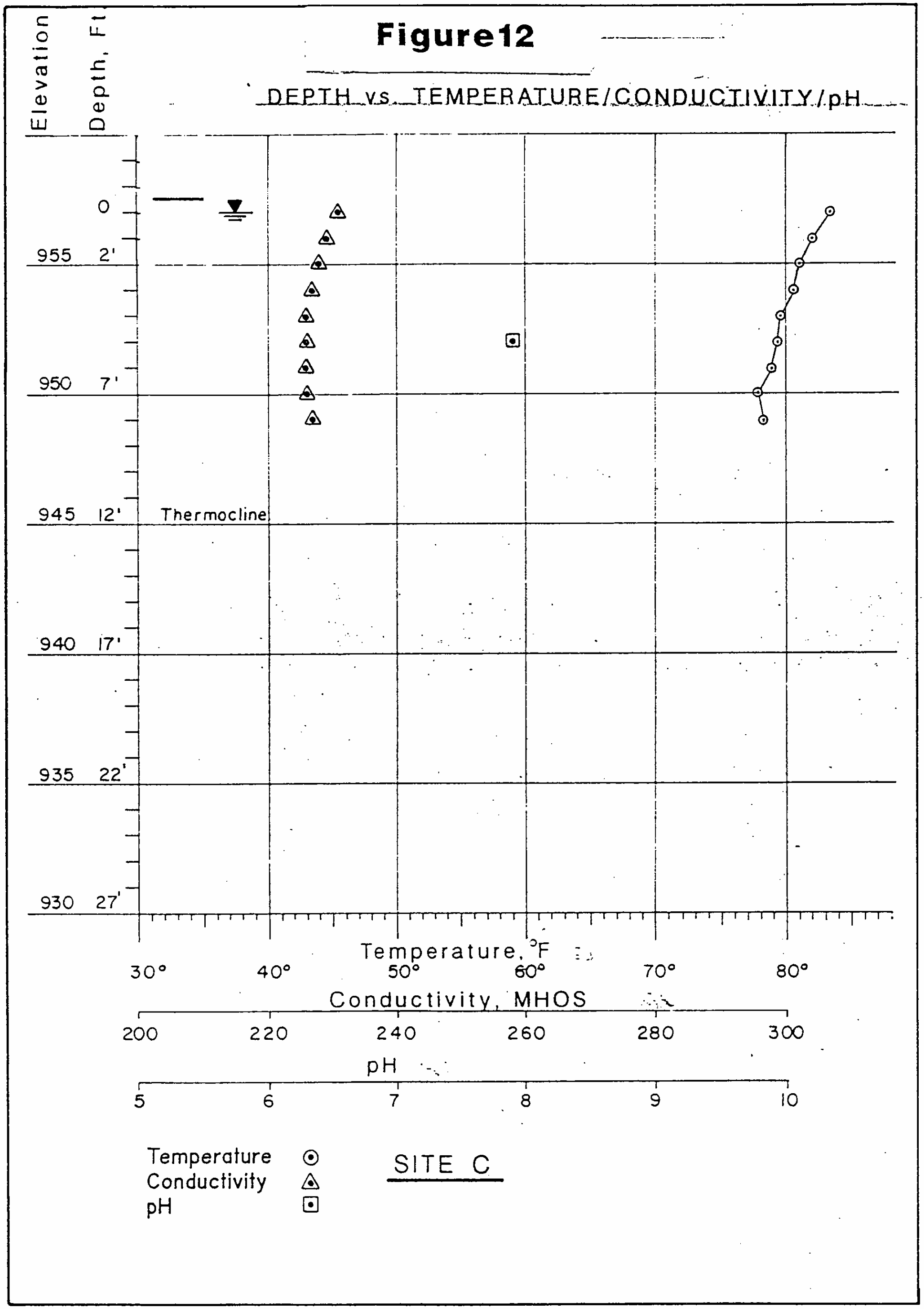
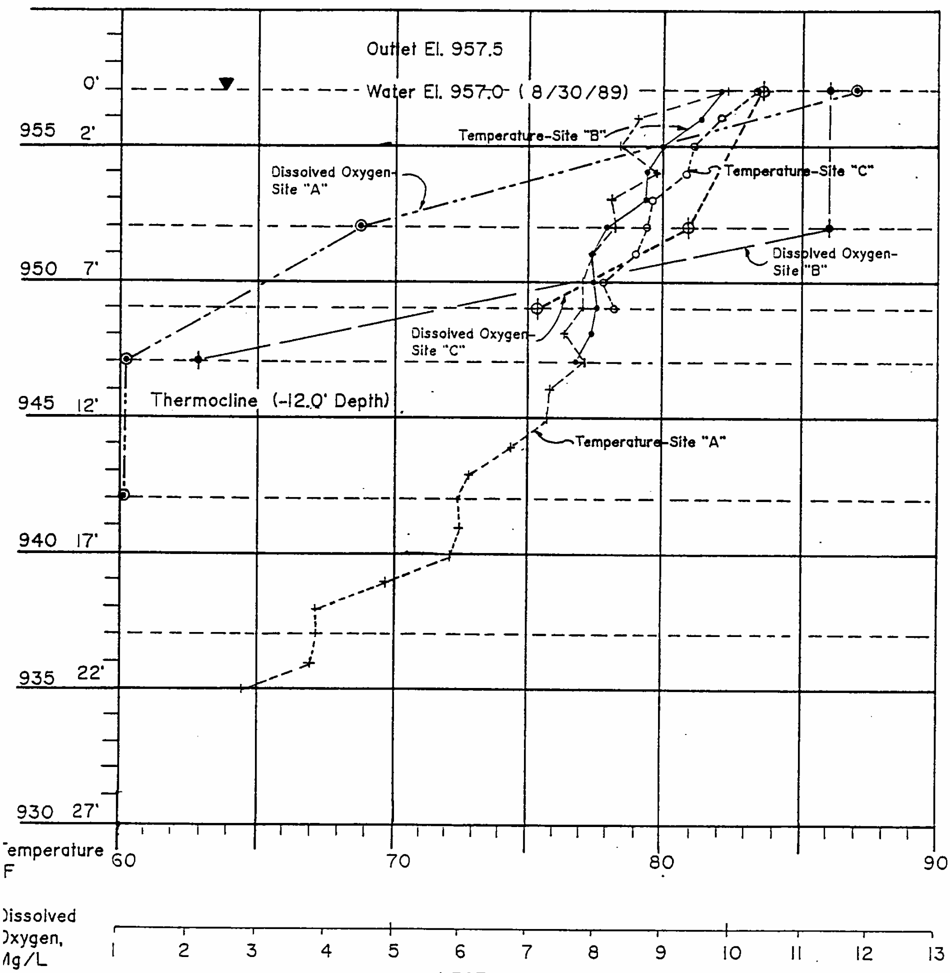


Figure12
DEPTH vs. TEMPERATURE/CONDUCTIVITY/pH
Elevation
Depth, Ft
0
955 2'
950 7'
945 12'
940 17'
935 22'
930 27'
Thermocline
Temperature, °F
30° 40° 50° 60° 70° 80°
Conductivity, MHOS
200 220 240 260 280 300
pH
5 6 7 8 9 10
Temperature
Conductivity
pH
SITE C

Figure 13

DEPTH vs. TEMPERATURE / DISSOLVED OXYGEN



LEGEND

Site	LOCATION A	LOCATION B	LOCATION C
Dissolved Oxygen	⦿	◆	⊕
Temperature	+	•	○

Figure 14

DEPTH vs. KJELDAHL NITROGEN

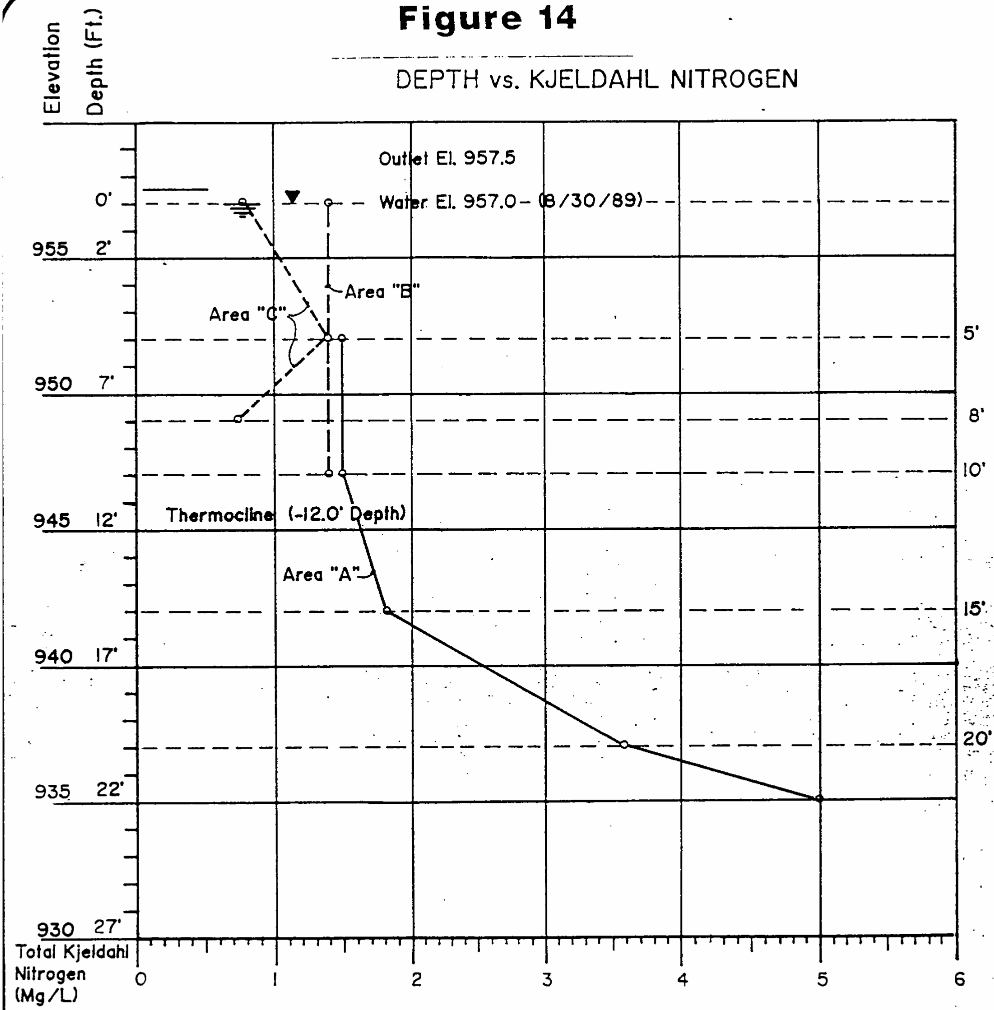
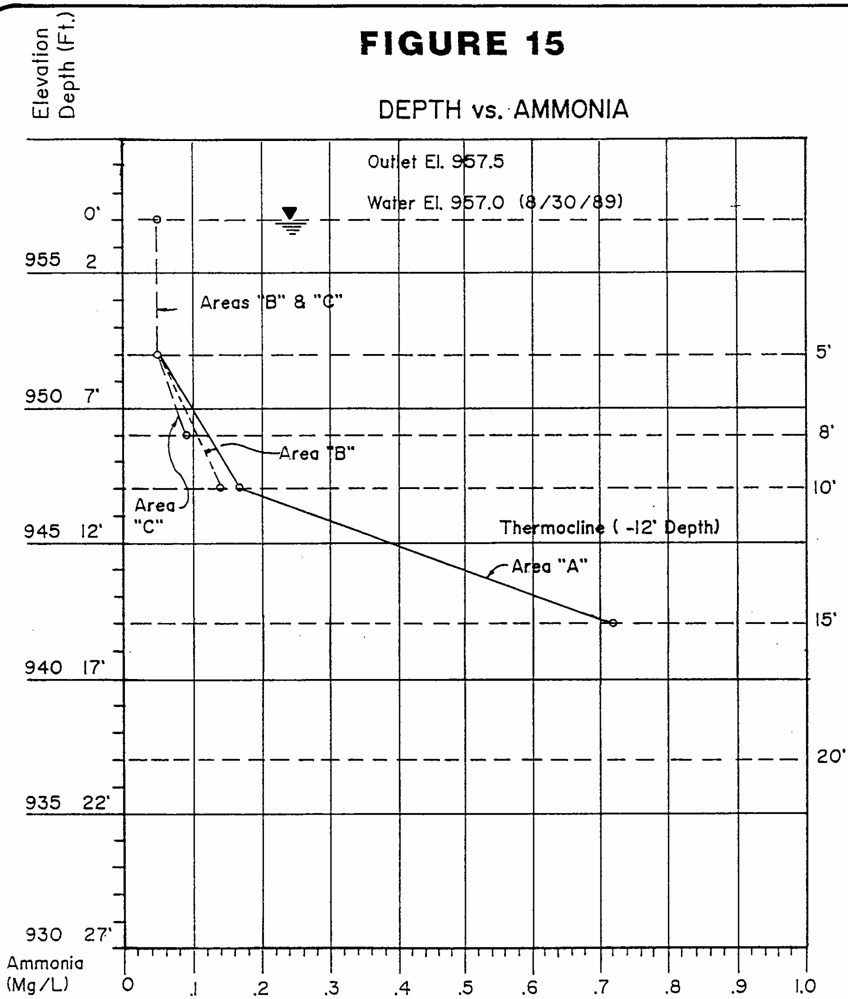


FIGURE 15

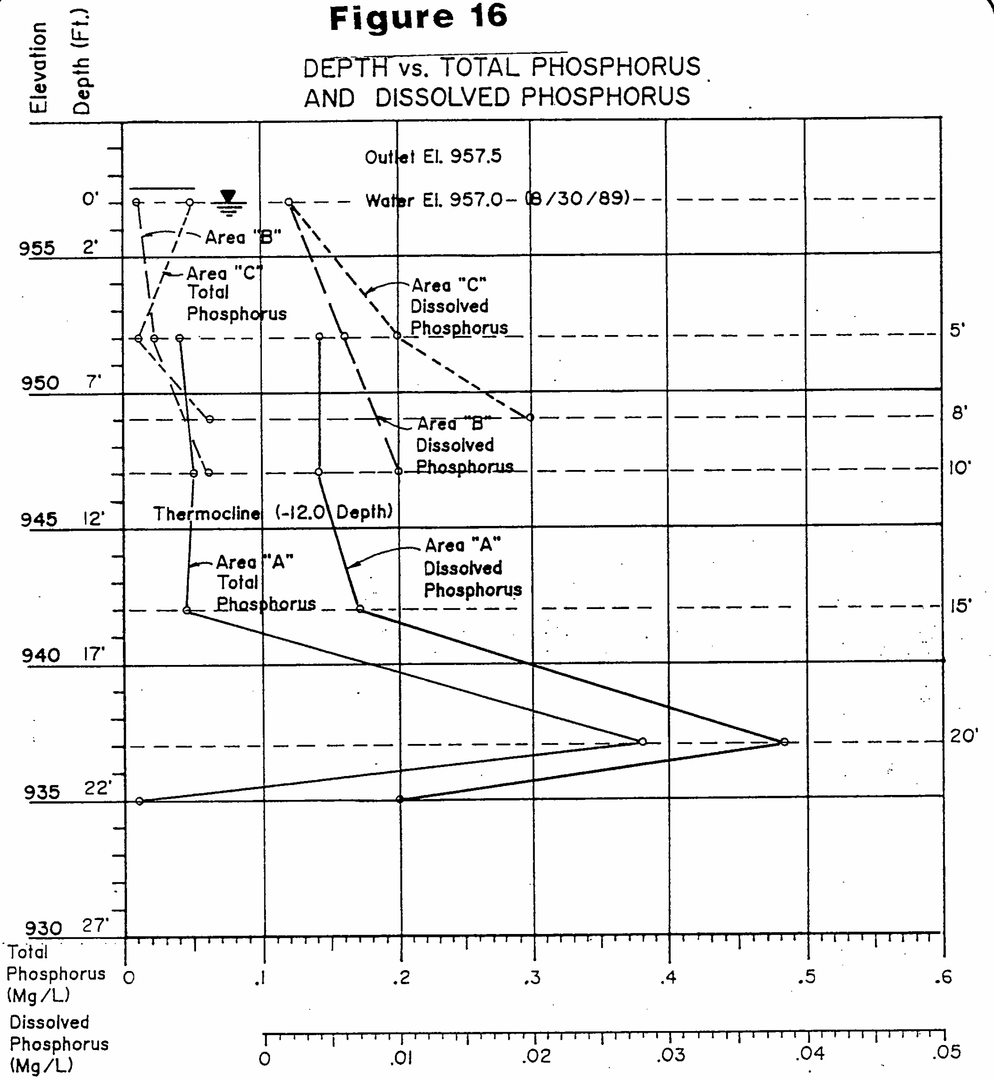
DEPTH vs. AMMONIA



Note: Area "A" data at 20' and 1' from bottom ommitted as erroneous.

Figure 16

DEPTH vs. TOTAL PHOSPHORUS AND DISSOLVED PHOSPHORUS



Surface samples for all three sites show consistently higher values of total phosphorus but lower totals of suspended solids. The total suspended solids appeared to increase with depth in the main reservoir. In the tributaries (at sites B and C), suspended solids were relatively constant at the surface, increased below the surface, and then decreased slightly just above the sediment. A possible reason for this was that samples from site B and C had experienced some degree of inflow within 24-hours preceding removal and testing, due to recently occurring precipitation.

Conductivity increased slightly with depth at sites A, B, and C; pH decreased slightly with depth at site A and B.

As depth increased, the dissolved oxygen at site A, B, and C decreased to a depth of ten feet. Beyond ten feet, the dissolved oxygen at site A decreased drastically below the thermocline to less than 1 milligram per liter (mg/l). Dissolved oxygen was nearly absent below an approximately 20 foot depth.

BATHYMETRY:

The bathymetric data estimated for this study indicates that the water depth in Bischoff Reservoir reaches a maximum of 24 feet at mid-reservoir near the outlet structure. The 1963 map (see Sheet 1 in Appendix B) produced by the United States Geological Survey and the IDNR showed similar depth contour lines, but indicated that the maximum depth was 27 feet. Most of the reservoir has experienced a degree of sedimentation with an overall average of 1.6 feet. Volume estimates indicate that approximately 379 acre feet of sediment have been deposited in the reservoir over the last 26 years, thus reducing its surface area to 190 acres. The storage-depth curve (see Figure 4 on page 23) shows that 379 acre feet have been lost since the 1963 survey. This represents a ten acre loss over 28 years. At best, these results are only estimates of the true sedimentation in Bischoff Reservoir. They are presented to give a general picture of the sedimentation in the reservoir. The inlet tributaries showed the greatest loss, at approximately six acres of surface area, while the remaining shorelines constituted the remaining four acres of surface loss.

SEDIMENT SAMPLES:

The sediment analysis indicated that organic matter was a major portion of the sediments in the two sites measured. (See Appendix A for the sediment sampling results.) Of particular importance is the fact that at site B, a very large concentration of decomposing blue-green algae hydrocarbons were found in the soil. Sediment samples were not taken at site A. Sites B and C had similar values for most parameters with the exception that site B showed an 1800 milligrams per kilogram (mg/kg) hydrocarbon deposit in the top layer of sediment. This condition may be attributed to decomposition of blue-green algae.

Table 9

MAXIMUM BACKGROUND CONCENTRATION OF POLLUTANTS IN INDIANA STREAM AND LAKE SEDIMENTS.

PARAMETER	MAXIMUM BACKGROUND (MG/KG)	PARAMETER	MAXIMUM BACKGROUND (MG/KG)
Aluminum	9400	Silver	<0.5
Antimony	0.49	Strontium	110
Arsenic	29	Thallium	<3.8
Beryllium	0.7	Zinc	130
Boron	8.0	Phenol	<0.2
Cadmium	1.0	Cyanide	<0.1
Chromium	50	PCB (Total)	0.022
Cobalt	20	Chlordane	0.029
Copper	20	Dieldrin	0.033
Iron	57000	DDT (Total)	0.020
Lead	150	BHC (Total)	0.014
Manganese	1700	Pentachlorophenol	0.003
Mercury	0.44	Heptachlor	0.002
Nickel	21	Aldrin	0.0007
Nitrogen (TKN)	1500	HCB	<0.001
Phosphorus	610	Methoxychlor	<0.001
Selenium	0.55	Endrin	<-0.001

Table 10

CRITERIA USED FOR GROUPING SEDIMENTS INTO LEVELS OF CONCERN.

High Concern:

Any contaminant present in concentrations greater than 100 times background.

Medium Concern:

Any contaminant present in concentrations 10 - 100 times background.

Low Concern:

Any contaminant present in concentrations 2 - 10 times background.

Unknown Concern:

Contaminants present for which a background concentration has not been established.

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Indiana Department Of Environmental Management
Office Of Water Management

Phenol concentrations at Site B (1.740 mg/kg) and Site A (3.44 mg/kg) exceeded the maximum background concentration for phenol (0.2 mg/kg) in Indiana stream and lake sediments. Copper concentrations at site B (24 mg/kg) exceeded the maximum background concentration for copper (20 mg/kg) in Indiana stream and lake sediments. Cyanide levels at site C (0.19 mg/kg) exceeded the maximum background concentration of cyanide (greater than 0.1) in Indiana stream and lake sediments. See Tables 9 and 10 for identification of maximum background concentrations and criteria for grouping sediments into levels of concern.

BACTERIOLOGICAL:

According to Environmental Protection Agency 1986 guidelines, the suggested water quality standard for general recreation use (not intended for swimming) is a maximum of 200 counts per 100 mL. Fecal coliform cells were found in all samples areas at concentrations equal to or just over 200 counts per 100 mL. See Table 8 on page 27.

STREAMFLOW:

The downstream flow (approximately 100 GPM) from the reservoir was due only to seepage from a spring located just downstream of the dam. (See photo 3 in Appendix C.) The flow had an oily film on the surface.

PHYTOPLANKTON:

Phytoplankton identification and enumeration shows that the algae community in the Bischoff Reservoir in August 1989 was dominated by the blue-green algae species' Microcystis; and by the green algae species' Scenedesmus. Also present were five species of Bacillariophyceae (Diatoms): Cymbella sp., Navicula sp., Synedra sp., Fragilaria sp., and the Gomphonema sp.. The Desmidaceae (Desmids), Cosmarium spp., and the Euglenoid genus Phacus were also identified. Samples taken from Bischoff Reservoir represent five major families of Phytoplankton with nine generalized species easily identifiable. See Table 11.

ZOOPLANKTON:

The Zooplankton was relatively diverse with the Copepoda species Cyclops and the immature larval nauplii stage (see Table 12). Also, two particular species of Cladocera were found: Daphnia spp. and Bosmina sp. These species feed primarily on phytoplankton. However, the blue-green algae species abundant in Bischoff Reservoir are usually unpalatable or indigestible to many of the zooplankton. Other less abundant algae species, especially the green algae, are the probable food source for Bischoff's many zooplankton.

TABLE 11

BISCHOFF RESERVOIR PHYTOPLANKTON IDENTIFICATION AND NUMBER/ML.*

	Site A	Site B	Site C
Cyanophyta (Blue-Green algae)			
Microcystis spp.	35025	28578	25010
Chlorophyceae (Green algae)			
Scenedesmus spp.	78	52	48
Bacillariophyceae (Diatoms)			
Cymbella sp.	15	10	9
Navicula sp.	20	18	15
Synedra sp.	12	7	9
Fragilaria sp.	18	10	12
Gomphonema sp.	5	3	3
Desmidaceae (Desmids)			
Cosmarium spp.	19	10	12
Euglenophyceae (Euglenoids)			
Phacus spp.	6	5	4
Total Number of cells/ml	35,198	28,693	25,122
Number of mls subsampled	3	3	3
Number of grids counted	50	50	50

*Samples Collected August 30, 1989

TABLE 12

BISCHOFF RESERVOIR ZOOPLANKTON IDENTIFICATION AND NUMBER/ML.*

Copepoda			
Cyclops spp.	0.80	.052	0.55
nauplii	3.2	1.5	1.2
Cladocera			
Daphnia spp.	0.25	0.15	0.12
Bosmina sp.	0.11	0.10	0.11
Total Number of zooplankters/ml	4.36	2.27	1.98

TABLE 13

BISCHOFF RESERVOIR MACROPHYTE IDENTIFICATION AND RELATIVE DOMINANCE RANKING.*

Samples Collected August 30, 1989

Emergents	High	1	2	3	4	5	Low
Typha sp. (Cattail)		X					
Pontederia sp. (Pickerelweed)							X
Sagittaria spp. (Arrowhead)						X	
Submergents							
Myriophyllum exalbescens (Water Milfoil)						X	
Najas flexilis (Bushy pondweed)							X

*Samples Collected August 30, 1989

AQUATIC VEGETATION:

A visual aquatic plant survey of Bischoff Reservoir was conducted to quantify the distribution of floating submergent and emergent aquatic macrophytes. Species of plants were collected and identified. The aquatic vegetation survey documented the presence of emergent and submergent species (see Table 13). The major emergent species includes Cattail (*Typha sp.*), Pickerelweed (*Pontederia* sp.), and Arrowhead *Sagittaria* Spp.). The major submergent species is the Water Milfoil (*Myriophyllum exalbescens*) and Bushy pondweed (*Najas flexilis*), which was found at approximately eight foot depths. The cattails are predominant at the inlet end and along the margins in recently deposited sediments that are built up due to suspended solids settling out in the relatively calm waters of the reservoir margins. From a depth of zero to approximately six feet, ranging from 20 to 50 feet from the shoreline, the predominant vegetation is cattails. Considerable underwater organic growth is noted in approximately 50% of the reservoir.

SECTION III - DISCUSSION

This section evaluates and discusses the data that was collected and reviewed for this study. The objective was to define the current conditions in Bischoff Reservoir and the mechanisms that have been responsible for these conditions.

3.1 - THE ISBH TROPHIC INDEX ASSESSMENT:

The Indiana Lake Classification System and Management Plan provides a mechanism for identifying the appropriate management group for a particular lake. One element that goes into determining a lake's management group is its trophic status. A lake's trophic status, in turn, is determined by its Eutrophication Index (EI) value. Data collected from sample site A was used in determination of Bischoff Reservoir's EI value. Using the water quality data collected during the field survey of August 29 and 30, 1989, a Eutrophication Index value of 47 was calculated. Table 14 presents the details of this calculation.

The light transmission photocell was estimated to be 14%, leading to assignment of three points. The nitrate was determined to be in the order of .10 part per million which constitutes zero points.

3.2 - HYDROLOGICAL CONDITIONS:

The principle hydrologic parameter of interest in evaluating the trophic status of Bischoff Reservoir and developing a restoration strategy is the hydraulic detention time. This is defined as the average time required for the volume of the reservoir to be completely replaced, and may be estimated from annual runoff, watershed area, and reservoir volume.

The U.S. Geological Survey has published the average annual runoff conditions for the 48 contiguous states. The region containing Ripley County has an average annual runoff of approximately 13.5 inches. Thus, the 2,980 acre Bischoff Reservoir watershed may be expected to produce approximately 3,127.5 acre feet of runoff annually. In addition, the reservoir will receive approximately 39.5 inches of direct rainfall annually, and lose approximately 28 inches in evaporation. Based upon a mean depth of 8.1 feet and a surface area of 190 acres, Bischoff Reservoir presently has a volume of approximately 1,541 acre feet. Thus,

TABLE 14

ISBH LAKE EUTROPHICATION INDEX CALCULATION
BISCHOFF RESERVOIR

Parameter and Range		Eutrophy Points	Range Observed	Points
I.	Total Phosphorus (ppm)			
	A. At least 0.03	1		
	B. 0.04 to 0.05	2		
	C. 0.06 to 0.19	3	X	3
	D. 0.02 to 0.99	4		
	E. 1.0 or more	5		
II.	Soluble Phosphorus (ppm)			
	A. At least 0.03	1		
	B. 0.04 to 0.05	2		
	C. 0.06 to 0.19	3	X	3
	D. 0.02 to 0.99	4		
	E. 1.0 or more	5		
III.	Organic Nitrogen (ppm)			
	A. At least 0.5	1		
	B. 0.06 to 0.8	2		
	C. 0.09 to 1.9	3	X	3
	D. 2.0 or more	4		
IV.	Nitrate (ppm)			
	A. At least 0.3	1		
	B. 0.04 to 0.8	2	X	0
	C. 0.09 to 1.9	3		
	D. 2.0 or more	4		
V.	Ammonia (ppm)			
	A. At least 0.3	1	X	1
	B. 0.04 to 0.5	2		
	C. 0.06 to 0.9	3		
	D. 1.0 or more	4		
VI.	Dissolved Oxygen			
	Percent Saturation of 5 feet from surface			
	A. 114% or less	0	X	0
	B. 115% to 119%	1		
	C. 120% to 129%	2		
	D. 130% to 149%	3		
	E. 150% or more	4		

The Eutrophication index is derived from the parameters listed on page 36 and 37 in the Indiana Lake Classification System and Management Plan.

TABLE 14 - CONTINUED

ISBH LAKE EUTROPHICATION INDEX CALCULATION
BISCHOFF RESERVOIR

Parameter and Range		Eutrophy Points	Range Observed	Points
VII.	Dissolved Oxygen Percent of measured water column with at least 0.1 ppm dissolved oxygen			
	A. 28% or less	4		
	B. 29% to 49%	3		
	C. 50% to 65%	2	X	2
	D. 66% to 75%	1		
	E. 75% to 100%	0		
VIII.	Light Penetration-Secchi Disc			
	A. Five feet or under	6	X	6
IX.	Light Transmission-Photocell Percent of light transmission at a depth of 3 feet			
	A. 0 to 30%	4	X	4
	B. 31% to 50%	3		
	C. 51% to 70%	2		
	D. 71% and up	0		
X.	Proposed Eutrophy Point Scale for Plankton*			
	A. Less than 3,000 organisms/L	0		
	B. 3,000 - 6,000 organisms/L	1		
	C. 6,001 - 16,000 organisms/L	2		
	D. 16,001 - 26,000 organisms/L	3		
	E. 26,001 - 36,000 organisms/L	4		
	F. 36,001 - 60,000 organisms/L	5		
	G. 60,001 - 95,000 organisms/L	10		
	H. 95,001 - 150,000 organisms/L	15	X	15
	I. 150,001 - 500,000 organisms/L	20		
	J. 500,001 - 950,000 organisms/L	25		
	K. Greater than 950,001 organisms/L	25		
	L. Blue-Green Dominance	10 additional points	X	10
		Total Eutrophy Score		47

* Use of this point scale is currently awaiting approval by the IDEM.

the reservoir's detention time was estimated to be 154 days. Total inflow water on the reservoir is 658 acre feet of water per year. Water from runoff is 3,127 acre feet, for a total of 3,785 acre feet.

Short detention times in reservoirs result in rapid flushing and retention of a relatively smaller fraction of total nutrient loading than would be retained in similar reservoirs with longer detention times. From the perspective of reservoir restoration, this means that Bischoff Reservoir is likely to have a relatively rapid response to a reduction in external nutrient loading. Moreover, accumulated sediment nutrients would be subject to reduction by flushing effects as released nutrients are washed out of the system and not replaced by external loads.

3.3 - WATER QUALITY:

The in situ water quality data indicate that Bischoff Reservoir was generally well mixed and not thermally stratified in the upper reaches of the reservoir, but only stratified in the deeper portion near the intake structures when sampled. The observed water column temperature and dissolved oxygen profiles are characteristic of relatively shallow productive reservoirs. The water column data indicate that there was very low dissolved oxygen below the thermocline at 10 to 12 feet. Supersaturation was apparent in the surface sample taken from sample site A, B, and C. This suggests that the highly productive algae population is present.

The mean total phosphorus (TP) concentration was relatively high at approximately .10 mg/L, or ten times the detection limit. A concentration of significantly higher value, namely 0.38 mg/L, was recorded in August 1989 (see Table 8). Seasonal and transitional meteorological effects serve as driving influences in this reservoir. Therefore, observed nutrient concentrations are expected to be variable over relatively short periods.

The ammonia concentrations at sampling site A were 0.17 to 4.2 mg/L between 10 to 20 feet and the nitrate-nitrite concentrations were low at 0.10 throughout the water column. These values indicate that nitrogen is not the limiting nutrient to algal growth, and substantiates the conclusion that phosphorus is the limiting nutrient in the lake.

Although it is insufficient to characterize all of the contamination as being conclusively that of the town of Morris, it would appear that very significant sources of nutrients arrive at the reservoir through the watershed. Furthermore, these nutrients are sufficient to substantiate and proliferate the blue-green algae.

3.4 - ALGAE POPULATIONS:

The phytoplankton data indicate that Bischoff Reservoir has a highly productive algae population dominated by the blue-green species, which is typical of highly eutrophic systems.

3.5 - LAKE SEDIMENTS:

The reservoir sediment core data, visually and analytically, indicate that the surficial sediments in Bischoff Reservoir are primarily composed of a silty clay with a significant organic content. Results of the sediment analysis indicate that concentrations of phenol, copper, and cyanide exceeded the maximum background concentrations of pollutants in Indiana stream and lake sediments. Table 10 lists the ranges for contaminants that are considered to be of low, medium, and high levels of concern. Phenol exceeded the maximum background level by 8.7 times at site B, thus placing it in the category of low concern. At site C, phenol exceeded the maximum background level by 17.2 times, thus placing it in the category of medium concern. Copper concentrations exceeded the maximum background level at site B by 1.2 times and thus are of low concern. Cyanide levels were found to be 1.9 times greater than maximum background levels at Site C and thus are of low concern.

The phenols and the cyanide in the southern branch probably result from pesticides and insecticides used in farming operations, or from the control of pests in and around the feed lots.

The observed characteristics of the sediment in Bischoff Reservoir indicates that there are probably significant sources of internal nutrient loading, especially under the anoxic conditions (site A) that appear to dominate the sediment water interface. Bottom samples could not be taken from site A because the depth of the reservoir exceeded the length of the grab bucket. However, water samples taken at 15 feet (see supplementary data for site A in Appendix A) had a hydrogen sulfide odor. With a significant reduction of external nutrient loading, this internal nutrient source may be sufficient to sustain eutrophic conditions albeit, less severe than currently exist in the reservoir. The sediment on the north branch also had a high oil and grease constituent.

If trophic conditions continue to decline even after significant reductions in external loadings have been achieved, the problem of internal nutrient loading may need to be addressed.

3.6. - IDENTIFIED NUTRIENT SOURCES:

The high concentrations of nutrients in the northern branch of the reservoir appear to stem from the town of Morris, residential development, pipeline transportation, and the truck terminal on the north branch feeding into this tributary of Bischoff Reservoir watershed. It is likely that overflows from the septic fields in Morris are fairly numerous, although there are no records being kept by the County Health Officers.

It must be emphasized that these facilities have been identified because of their relatively large size. Conclusions cannot be drawn that these facilities are the sole source of the nutrient contamination of this sub-basin. There are several hog lots and cattle feeding areas within the watershed that may also contribute to the poor water quality.

It can be inferred that a large fraction of the nutrients entering the reservoir from the watershed is washed off during rain storms and transported by the stormwater. Dust, oil, grease, spill garbage, and other litter may come from relatively large residential areas in the north branch of the watershed.

Farming operations are sources of nutrients. Specifically, the spread of animal waste as part of the fertilization process, the use of fertilizers and pesticides, and the runoff of wash waters from fertilizer and seed facilities all contribute to surface water pollution.

3.7 - LAND USE PRACTICES:

Land use activities in the watershed represent potential sources of nutrient loading to Bischoff Reservoir. Effective restoration of the reservoir must address and control the impact that land use activities have on nutrient loading.

The erosion data presented on Figure 6 on page 19 indicates that approximately 13 percent of soils in Bischoff Reservoir's perimeter and within the watershed are erodible. These soil types include Avonburg-Rossmoyne-Cincinnati silt loam which have the highest soil erodibility factors in Indiana. This indicates that extensive erosion control practices should be implemented in agricultural areas and during construction activities. Sites were observed where livestock have access to the banks of the streams, which also erodes streambanks.

Erosion during construction activities must be controlled. Numerous housing developments are being constructed in the vicinity of the northern branch of the reservoir. Erosion control practices can mitigate this problem, as can more strident local enforcement of construction activities.

SECTION IV - IDENTIFICATION OF POTENTIAL SOLUTIONS

This section discusses technological solutions that are available for addressing the problems in Bischoff Reservoir. Potential solutions can be divided into two broad categories: watershed management measures and in-reservoir restoration techniques. Section 4.1 focuses on watershed management techniques that can reduce nutrient loading to, and transport in, the streams and reservoir. Section 4.2 discusses strategies for in-reservoir restoration, including sediment removal and in situ treatment methods. The majority of the proposed solutions were extracted from the EPA's 1988 "Lake and Reservoir Restoration Guidance Manual". Figure 17 summarizes proposed solutions and identifies the location where individual solutions should be implemented.

4.1 - WATERSHED MANAGEMENT:

Watershed management is critical to effectively reducing nutrient loading to Bischoff Reservoir. Issues such as agricultural and urban erosion control, runoff control and treatment, and animal and human waste management must be addressed. Table 15 presents several "Best Management Practices" (BMP's) available for the control of urban runoff. The Hoosier Heartland Resource Conservation and Development Council's (HRCDC) Urban Planning and Development Guide describes several categories of sediment control measures for urban erosion control: sediment basins, sediment filters, and mud and dust control. The Urban Planning and Development Guide describes these erosion control measures as follows:

SEDIMENT BASINS:

The purpose of a sediment basin is to prevent the deposition of sediment in downstream areas by trapping sediment in ponded water during storms. Sediment basins should be large enough to store the expected sediment yield from a construction site, as well as runoff from the design storm.

Basins can be constructed in small natural drainageways or in low areas below the disturbed sites, to trap sediment laden runoff before it enters the stream. Basins should never be located in live streams.

SEDIMENT FILTERS:

There are three type of filters: vegetative filters, straw bale filters, and filter fences. The vegetative filter is a strip of grassed area through which storm water can flow before it enters streets, storm sewers, grassed channels, and reservoirs. As water flows through the grass strip, sediment is removed by filtering and by deposition as flow velocity is reduced.

TABLE 15

BEST MANAGEMENT PRACTICES AVAILABLE FOR THE CONTROL OF URBAN RUNOFF*

SOURCE CONTROLS:

- Increased Infiltration
- Retention
- Erosion Control
- Street Sweeping
- Fertilizer Management

REDUCTION IN DELIVERY TO RECEIVING WATERS:

- Stormwater rerouting
- Infiltration and Sedimentation Basins
- Flow Equalization
- Physical, Chemical, and Biological Treatment

* (Cook, et al., 1986)

TABLE 16

TYPICAL COSTS OF SELECTED URBAN BMPS

MANAGEMENT PRACTICE	SIZE	COST (1985 $)
Dry Pond/Extended Detention Basin	50,000 ft^3	$18,700
Wet Pond	50,000 ft^3	20,400
Infiltration Trench	3,600 ft^3	4,600
Grit Separators	n/a	7,500
Grassed Swales	15 ft. x 150 ft.	750

(Scheuler 1987)

Vegetative filters can be developed using existing vegetation or by planting prior to construction activities.

Straw bale filters are temporary barriers installed below small disturbed areas, at the base of a slope, or above a storm sewer inlet. The purpose of the filter is to intercept or detain sediment.

Filter fences are designed to slow the flow rate. Fences are composed of a wire support fence and an attached synthetic filter fabric. Filter fences tend to be more effective than straw bales.

MUD AND DUST CONTROL:

To control the transport of mud onto public roads, stone should be placed at construction entrances and exits. Dust can be controlled by phasing project tasks, using temporary stabilization measures following grading, or applying water to transport roads during dry periods.

Table 16 on page 48 presents cost estimates of selected best management practices. The EPA's 1988 "Lake and Reservoir Guidance Manual" describes Best Management Practices in detail.

EROSION CONTROL:

Streambanks should be protected and stabilized. During field reconnaissance of Bischoff Reservoir, it was observed that livestock have access to inlet streams. Livestock then destabilize streambanks. Fencing stream banks, a simple and inexpensive measure, would protect stream banks from livestock. Costs associated with this measure are those for constructing fences and for providing animals with alternative sources of water. Erosion control practices should also be implemented during construction of homes and roadways.

Urban erosion control practices, when properly implemented, can significantly reduce sedimentation into a waterbody. This is particularly important in the northern portion of Bischoff Reservoir, where residential areas are currently under construction. In the Hillendale Estates subdivision, for example, sediment entered the reservoir during construction despite the existence of an SCS approved erosion control plan. In all likelihood, the erosion control plan was incompletely or incorrectly implemented. Increased education on how to implement erosion control and additional monitoring and enforcement, are necessary. The various erosion control techniques recommended by the HRCDC (sediment basins and filters, mud and dust control) can be used to reduce urban erosion control problems. Local officials can signify the importance of erosion control in the city and county by passing an urban erosion control ordinance. Information on developing such ordinances can be found in a document published by the Highway Extension and Reserch Project and Indiana Counties and Cities entitled A Model Ordinance for Erosion Control on Sites with Land Disturbing Activities.

Other erosion control and soil conservation practices should be promoted within the watershed. Many of the T by 2000 procedures could be used, such as conservation cropping and tillage, critical area planting, terracing, and grade stabilization. The Soil Conservation Service (SCS) has published design criteria and provides guidance to individual farmers and land owners in the selection and implementation of erosion control measures. The local Soil and Water Conservation District office located in Versailles, Indiana, has developed a complete erosion control study program. This study, "Report on Bischoff Reservoir", is included in this report's bibliography.

RUNOFF CONTROL:

Stormwater runoff from any developed urban area will be contaminated by dust, animal waste, hydrocarbons, lawn fertilizers, and a wide range of other materials that are deposited on the ground or around buildings and washed off by rainfall and snowmelt.

Contaminated runoff is a serious problem in the watershed, particularly in the branch near Morris. The level of coliform, the degree to which algae is present, and the blue-green color of the water, all indicate the presence of contaminated urban runoff. Typically, BMP's for control of runoff are separated into two groups: source controls, and reduction of delivery to receiving waters. Table 15 on page 48 lists several types of practices and technology that are commonly used in managing urban runoff. The most applicable practices for Bischoff Reservoir watershed include installation of sanitary sewers in the town of Morris, and control of lawn fertilizer applications and erosion.

Pollutant removal from urban storm water may be accomplished by using wet and dry storm water detention ponds, grassed waterways, sedimentation basins, and artificial wetlands. Diversion techniques may also be used to reroute contaminated flows away from the critical waterways to other detention areas with similar capacities.

WATER QUALITY:

Many of the water quality problems in Bischoff Reservoir may be caused by eutrophic conditions in the water supply reservoir. Internal sources of nutrients can hinder efforts to control europhic conditions caused by external sources of nutrients. Eutrophic conditions can result in unpleasant tastes, odors, and colors in the water supply. Poor taste and odor are associated with algae blooms.

Other eutrophication-related problems in water supply systems include a gradual loss of water storage as silt deposits increase, rapidly escalating costs connected with increased use of chemicals to clean the raw water, and in-plant problems such as clogged filters.

Drinking water quality could be improved by upgrading in-plant treatment. Plant modifications to enable facilities to remove organics can be costly. Therefore, an efficient approach to improving water quality would be to eliminate or reduce the introduction of substances that decrease water quality. The following description from the EPA 1988 guidance manual summarizes the need for comprehensive management of a reservoir with respect to water quality.

> "The better the incoming water, the less it will cost to finish potable water. Ultimately, watershed and reservoir protection and restoration may be less costly than extensive in-plant modifications. As already pointed out, however, reservoirs are very difficult to protect because their drainage basins are often large relative to reservoir area and usually include several political and economic units. The city or controlling authority may have to embark on a long-term effort to buy land, encourage or subsidize wastewater treatment plant upgrades, and help land users to employ modern agricultural practices.
>
> As previously noted, algae blooms, particularly blue-green algae, not only can impart an unacceptable taste and odor but can also increase the demand for treatment chemicals, and decrease filter runs. There are few solutions if nutrient diversion is not adequate. Artificial circulation could reduce productivity of algae in deep reservoirs, but is unlikely to be effective in shallow ones. Sediment removal and especially phosphorus inactivation, both procedures to curtail sediment nutrient release, will eventually be overwhelmed by high loading, but offer the possibility of improvement for several years.
>
> Copper sulphate, an algicide, can be used for short-term relief, but applications are often followed by more severe blooms and by release of substances that add to Trihalomethane (THM) production." (US EPA) <u>The Lake and Reservoir Restoration Guidance Manual, First Edition</u>, 1988.)

<u>WASTE MANAGEMENT</u>:

Animal waste and human waste appears to be a problem throughout the watershed. Fecal contamination was evident in every sampling site (see Table 8 on page 27 for data on sample sites). The general principle of proper waste management focuses on the minimization of contamination and the adequate treatment of contaminated flows. This could be accomplished in Morris by the installation of sanitary sewers and holding areas and treatment of waste at feedlots or other agricultural facilities. See the 1975 SCS "Agricultural Waste Management Field Manual" for guidance on implementing on-site waste management practices.

The cost for laying sewer lines is approximately $43.00 per linear foot for 12 inch plastic pipe, plus costs for excavation and backfilling. Costs will vary considerably depending on factors such as the depth at which the pipe is placed and soil type. Costs could approach as high as $80.00 per linear feet. Costs for holding areas vary depending on depth and size. In general, excavation costs can range from $1.45 to $2.50 per cubic yard.

4.2 - LAKE RESTORATION:

Considerable effort should be made to reduce external loading of nutrients to the reservoir. Problems in Bischoff Reservoir, such as aquatic plant management and decreasing reservoir depth, must be addressed through techniques such as drawdown of the reservoir and construction of sediment traps. However, if reductions in external loading fail to improve conditions in the reservoir, alternatives for curbing internal loading should be examined. The options that are available to deal with internal loading problems include aeration, sediment oxidation, and phosphorus inactivation.

RESERVOIR DRAWDOWN:

Reservoir drawdown can be an effective way to handle several different problems affecting Bischoff Reservoir, such as sedimentation and the growth of aquatic plants. The reservoir should be drawn down at least five feet to achieve the desired results. Determination of the exact level of drawndown should be coordinated among the Batesville Water and Gas Utility Company, the IDNR District Fisheries Biologist, and the IDNR Division of Water. Several factors need to be taken into account prior to a drawdown. These are:

1. Drawing the reservoir down for a period sufficient to expose plants to subfreezing, dry conditions for several days to several weeks.

2. Once undertaken, staggering over-winter drawdowns to prevent aquatic plants from adapting to the two years without a drawdown.

3. Inspecting weather records to help predict the availability of sufficient runoff, to allow for completed refilling of the reservoir during the desired refill period.

An "over winter" reservoir drawdown would enhance the quality of Bischoff Reservoir by oxygenating sediments, "freezing out" aquatic vegetation, and consolidating loose organic sediments (thereby rendering sediment removal to increase the depth in embayment areas unnecessary).

Disadvantages of drawing the reservoir down include restriction of the availability of adequate water supplies, increased algal blooms after the drawdown, and fish kills caused by depletion of oxygen in the remaining pool.

It should be noted that a partial drawdown (as opposed to a complete drawdown) would be sufficient to handle current problems in the reservoir. However, a complete drawdown may be useful in the future if it becomes necessary to increase the depth of the main body of the reservoir or to control internal nutrient release.

SEDIMENT CONSOLIDATION:

Sediment consolidation is a possible way to increase reservoir depth without dredging or excavation (Wedepohl, et al. 1983). Sediment consolidation involves drawing the reservoir down to below the surface of the sediments and removing the buoyant support of the water. The sediments then consolidate under their own weight. After a period of drying, the reservoir level is restored, with a net increase in depth.

AQUATIC PLANT CONTROL:

Drawing the reservoir down can help control aquatic vegetation. During a drawdown, nuisance plants are exposed to freezing and desiccation, or other harsh environmental conditions. A drawdown would help control populations of cattail and water milfoil observed in Bischoff Reservoir during the August 1989 site survey. Informal interviews with local residents also revealed that these plants are observable in the early spring, but less apparent later in the season.

SEDIMENT TRAPS:

Sediment traps are temporary structures designed to detain runoff for short periods so that heavy sediment particles will drop out. Sediment traps are most useful when placed within and adjacent to disturbed areas (such as construction sites). A crushed limestone sediment trap installed across the inlets of the reservoir up to elevation 960 could become a future siltation trap behind the dikes. Figure 18 shows a conceptual drawing of a siltation trap. Siltation traps should be designed in accordance with the SCS Technical Guide. There are six sites where siltation traps could be constructed: three on the southern prong and three on the northern prong of the reservoir. Figure 17 shows the locations of the proposed siltation traps. The traps should be constructed in order of benefits provided. In general, the three siltation traps on the southern prong should be constructed first. Then, depending on the availability of resources, the trap proposed for the middle location on the northern prong (see Figure 17) should be constructed first, followed by the trap proposed to the left, and then the trap proposed to the right. The dikes for the siltation traps should be constructed of limestone. Costs for construction of these traps can vary considerably, depending on factors such as size and material used. In general, costs can range as high as $300,000 per site.

4.3 - CONTROL OF INTERNAL NUTRIENT RELEASE:

Aeration, sediment oxidation, and phosphorus inactivation can be used to address taste and odor problems, and internal nutrient loading. These techniques should be investigated only if attempts to control external nutrient loading fail to improve the trophic conditions at Bischoff Reservoir.

AERATION:

Hypolimnetic aeration can be used to eliminate taste and color problems in the drinking water. During hypolimnetic aeration, the water is aerated by contact with the atmosphere, whereby carbon dioxide and methane are then lost, and the water is returned to the hypolimnion. Aeration in this way can control phosphorus release from lake sediments by promoting its combination with iron. However, aeration has an uncertain success rate and high capital and operation costs.

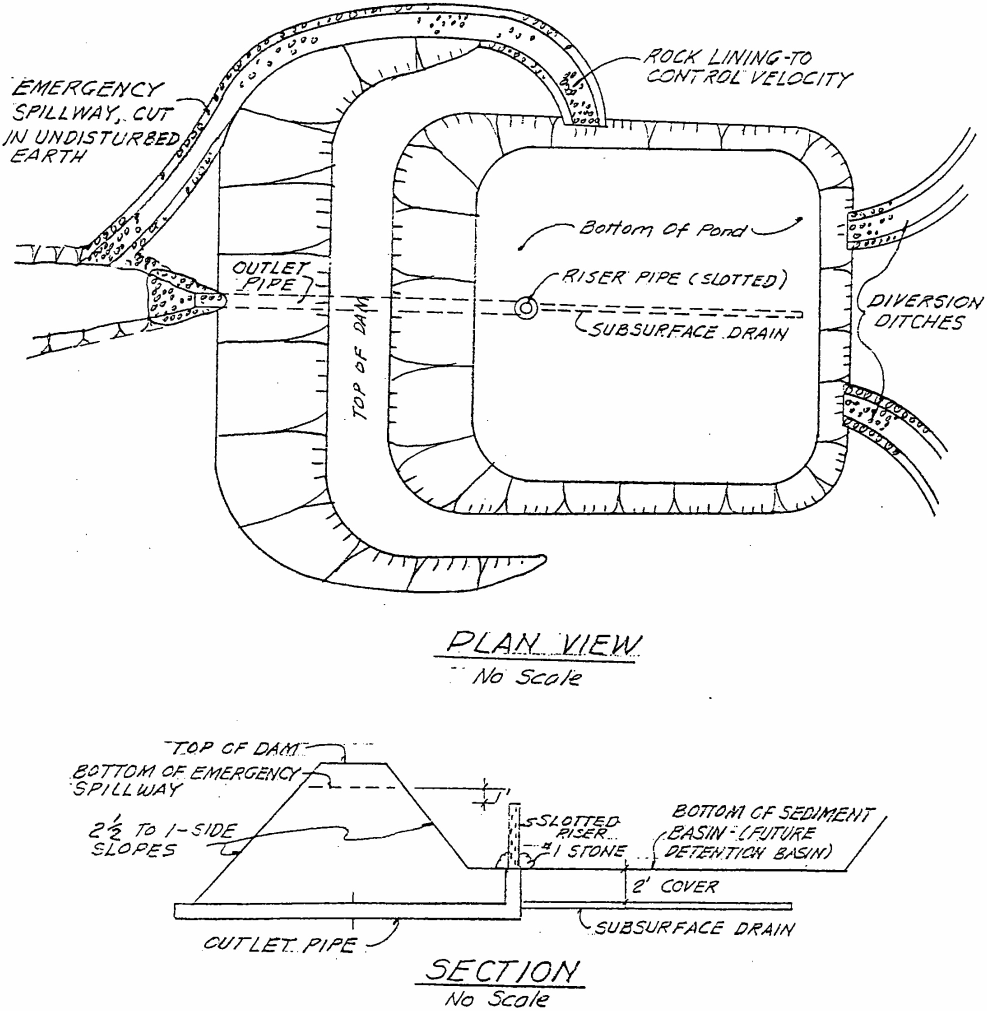
SEDIMENT OXIDATION:

Sediment oxidation can be used to decrease the release of phosphorus from sediments. Iron (as ferric chloride) is added to enhance phosphorus precipitation. Lime would also be added to the water body to bring the pH to a level optimum for denitrification. According to the EPA 1988 "Lake and Reservoir Restoration Guidance Manual" no negative impacts associated with sediment oxidation have been reported. Typical costs for sediment oxidation of organic sediment are approximately $3,034.00 per hectares, or approximately $233,618.00 (in 1983 dollars) to treat 75% of the sediment in Bischoff Reservoir.

PHOSPHORUS INACTIVATION:

In some cases, algal blooms continue despite reductions in external nutrient loading. Algal blooms are able to thrive because phosphorus stored in sediments are released into the water body. Phosphorus inactivation is a technique used to achieve long term control of phosphorus release from sediments. This technique works by adding large doses of aluminum sulfate to the water body which keeps the phosphorus concentration in the water column low enough to limit algal growth. However, aluminum sulfate can be toxic in high doses. Use of this technique, particularly in a water supply, is questionable for this reason. Use of this technique would require careful and continuous water quality monitoring. Typical costs for phosphorus inactivation are $350.00 per acre (1988 dollars).

Figure 18



CONCEPTUAL DRAWING-SILTATION TRAP

Reference:
"Urban Development Planning Guide for Erosion & Sediment Control"
Hoosier Heartland Resource & Development Council, Inc.
Fourth Edition

SECTION V - CONCLUSIONS AND RECOMMENDATIONS

5.1 - CONCLUSIONS:

Bischoff Reservoir suffers from external nutrient loading and sedimentation problems. The high nutrient concentrations in the lake, the occurrence of algal blooms, the dominance of blue-green algal in these blooms, the observed siltation and sedimentation, and the high Eutrophication Index score support this conclusion. Without implementation of restoration techniques, the conditions in Bischoff Reservoir are not expected to improve.

More specifically, the large amount of hydrocarbons in the reservoir bottom sediments, the lack of dissolved oxygen in the bottom three feet of the reservoir water, and the presence of fecal coliforms will continue.

The urban area in and around the town of Morris appears to be a significant source of nutrient and sediment contamination. Construction of residential developments has contributed significantly to urban erosion problems. Within this sub-basin, the church, cemetery, fertilizer and chemical distribution centers, agricultural fields, restaurant, and houses located on septic fields, are the most probable sources of significant discharges.

5.2 - RECOMMENDATIONS:

The condition of Bischoff Reservoir will not improve without implementation of restorative mechanisms. The focus of restoration procedures should be on watershed management techniques. However, in-reservoir actions are also necessary to restore the ecological health of Bischoff Reservoir. The following watershed management techniques should be implemented:

1. Implementation of Best Management Practices (BMP's) throughout the watershed coupled with extensive educational programs designed to make local residents aware of how various types of land uses affect water quality in Bischoff Reservoir. This should include the selection and implementation of appropriate animal waste management systems, erosion control practices, and fertilizer reduction practices.

2. The installation of sanitary sewers and treatment facilities in the town of Morris to improve the quality of Bischoff Reservoir.

3. Initiation of an "over winter" reservoir drawndown to oxygenate sediments, "freeze out" aquatic vegetation, and consolidate loose organic sediments. Drawing the reservoir down by at least five feet would expose most of the organic sediments. A drawdown would also be beneficial by helping to increase the depth in embayment areas. It should be noted that drawing the reservoir down could limit the availability of adequate water supplies, cause algal blooms after the drawdown or deplete the oxygen in the remaining pool, thus leading to a fish kill.

4. The installation of limestone sediment traps at the southeast and north eastern inlets to the reservoir should also be considered to provide filtration, but only after implementation of controls for the fecal coliform levels.

Efforts should be made to make all local residents aware of how land use activities affect the condition of Bischoff Reservoir. Particular emphasis should be placed on agricultural activities and urban erosion/runoff problems. Attention should also be paid to long-term changes in infrastructure, in order to eliminate problems associated with waste management.

Sediment consolidation and the creation of siltation traps are important mechanisms for improving the condition of Bischoff Reservoir. Some removal of the cattails and sediment could be accomplished provided that these sediments are not overloaded with heavy metals and contaminants such as copper, phenol, oil, grease, and fecal coliforms.

Of the in-reservoir alternatives, the most economical and likely to succeed would be drawing the reservoir down to consolidate sediments and control vegetation, and the construction of erosion control dikes on the inlet.

5.3 - DESIGN STUDY:

It is recommended that the Batesville Water and Gas Utility Company undertake a design study consisting of the following:

1. The identification and design of site specific BMP's. This should be done in cooperation with the Ripley County Soil and Water Conservation District office.

2. The design of sediment/siltation traps or similar treatment systems for the discharges that flow into the reservoir from the town of Morris and from the area adjacent to State Road 46.

3. The design of sanitary sewers within the town of Morris, with pumping to the Batesville Waste Water Treatment Plant for treatment.

4. The completion of an environmental impact assessment on downstream effects of an extended drawdown of Bischoff Reservoir. An environmental impact assessment will help to highlight any negative and positive impacts that a drawdown could have on nearby ecological systems. The assessment would evaluate the affects of a drawdown of vegetation, wildlife, fish populations, and land use. Should the assessment indicate the potential for serious negative impacts, the benefits of a drawdown will have to be reconsidered, and additional study would be necessary.

6. The investigation of funding options available to support implementation of the restoration measures.

5.3.2 - RESTORATION IMPLEMENTATION:

The restoration effort should begin with the implementation of agricultural and urban BMP's for controlling contaminated runoff throughout the watershed. Assistance with implementation of BMP's is available at the local and state level. Local sources of assistance include the Ripley County Soil and Water Conservation District (SWCD), the United States Department of Agriculture (USDA) Soil Conservation Service, and the USDA Agricultural Stabilization and Conservation Service. These organizations can provide information on federal and state cost-sharing programs for soil and water conservation efforts. The Batesville Water and Gas Utility Company may be able to work with the Riply County Soil and Water Conservation District and the SCS in implementing BMP's and providing information to local residents. It will probably take several years for most of the individual landowners, business leaders, and farmers to construct on-site controls and sanitary sewers within the town of Morris. Efforts should also be made to assist landowners in applying soil conservation practices. The agencies noted above can provide such assistance.

At the state level, the IDNR Division of Soil Conservation T-by 2000 Program can offer educational and technical assistance. The IDNR Urban Erosion Control Specialist can assist urban landusers with erosion control, work with planners and developers, and present programs an urban erosion control to interested groups.

A drawdown of Bischoff Reservoir should be conducted after most of the watershed controls have been put into operation. The drawdown should begin in September or October to allow the reservoir to be drawn down at least five feet and expose sediments during the dry period before the onset of winter snow and ice cover. However, the drawdown should be coordinated with the Batesville Water and Gas Utility Company, the IDNR District Fisheries Biologist, and the IDNR Division of Water, in order to determine the most appropriate depth for a drawdown. All excavation and construction should be scheduled for this period. The reservoir should be allowed to refill during the following spring. The available hydrologic information indicates that the reservoir should refill in approximately six months.

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INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
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January 28, 1988

Mr. Gary D. Doxtater
Lake Management Biologist
Division of Soil Conservation
Indiana Department of Natural Resources
FLXI, Purdue University
West Lafayette, Indiana 47906

Re: Water Quality Sampling Guidance

Dear Gary:

Ideally, we would sample a lake and its tributaries several times each summer. However, if only one survey can be conducted, it should be done during a period when the lake is strongly stratified (July or August). Following is a general outline of the sampling procedures we use to obtain data to calculate our trophic index number for a lake or reservoir.

Survey Procedure

(1) Calibrate the D.O. meter. Recalibrate whenever you believe that, for any reason, the instrument may have been disturbed.

(2) Observe the shoreline and fill in the observations on a data sheet. Particularly notice the weed development and collect what appears to be the major genera which may be causing a problem. Identify it if you can. If you can't, preserve it for later identification by an expert. Enter the name or names of the plants on the observation sheet.

(3) Using a depth meter, find the deepest part of the lake.

(4) Record secchi disc reading without sun glasses. (8" disc)

(5) Record light intensity readings at 3 feet and the level where 1% is present.

(6) Make a dissolved oxygen and temperature profile. Record the oxygen and temperature data on the observation sheet. Make a duplicate record in a notebook. If there is any doubt about an oxygen reading, recheck with a

winkler test. When and if the reading of 0.0 p.p.m. D.O. is reached, is important. Water with zero dissolved oxygen usually has the odor of hydrogen sulfide.

(7) Take an algal tows with a closing net.

A. 5 ft. level to surface. (in all lakes)

B. Make a five foot tow to include the beginning of the thermocline (in all lakes). For example:

Temp. °c

27.5
27.5
27.5
27.5
27.5 ______ End tow
26.
25.
24. 5 ft. tow
23.
22. ______ Begin tow
21

C. Empty the algal collection basket into a container after each sample collection while washing it down thoroughly with tap water from a squeeze bottle.

D. Preserve each algal sample with 3 ml. of formalin and mark the container with the lake name, date, and depth of the tow.

(8) Take the water samples:

A. At the 5 ft. level.

B. At the beginning of the thermocline.

C. As near as possible to 1 ft. off bottom.

Composite these three samples in a 2000 ml. plastic container by carefully measuring 650 ml. from the Kemmerer bottle at each sampling level.

Preserve the sample with 5 ml. of H_2SO_4.

Shake the sample well.

Pour 100 ml. of the sample into a separate plastic bottle and label it soluble P., lake name, and date.

Make out the field sheet clearly.

Total P
TKN
Nitrate
Ammonia

(9) Take a grab sample of all the lake's inlet and outlet streams at stations as near to the lake as possible. Preserve and prepare the samples as described in Section 8.

During rains, sample as many tributary streams as possible so we may get some idea of non-point nutrient contribution from these sources.

Septic tank evaluation should be a part of the survey. One way to accomplish this would be to count the number of dwellings within 100 meters of the lake. Unless a sewer system is available it is assumed that each dwelling is served by a septic tank. A determination of the number of people occupying each dwelling and period of occupancy should be made. A similar census for lakeside parks, resorts and campgrounds is also necessary. It has been estimated (EPA) that a satisfactory septic tank disposal system with absorption field will contribute approximately 0.1134 kg P and 4.263 kg N/capita/year to a lake.

In order to determine if there are any septic tanks that discharge directly to the lake, a dye testing program should be initiated in cooperation with the county health department. A bacteriological survey need not be conducted before the dye testing is initiated. We can offer advice on how this can be done.

Bacteriological sampling has been used in the past to indicate if a septic tank testing program was necessary. This only served to delay the dye testing. However, if you want to determine if whole body contact uses should be limited because of inadequately treated sewage entering the lake from septic tanks or upstream sewer system or treatment facility, bacteriological testing is necessary. Water sampling of the tributaries will provide information regarding bacterial contribution and nutrient loading from combined upstream sources.

When it is necessary to do bacteriological sampling, it should be coordinated with the county health department.

Under most circumstances, analysis for pesticides, herbicides and heavy metals is limited to sediment samples and/or samples of fish tissue. While it might be necessary to do this to qualify for a Section 314 (clean lakes) grant, it is probably not necessary for your purposes unless it is anticipated that in-place sediments will be disturbed or there is an indication that sediment contamination is likely to have occurred.

Specific sampling and field analysis techniques for various media are contained in our field and laboratory procedures manual. This is about 2½ inches thick and is not something that we provide to the public free of charge. However, it is available for public inspection in our office and xerox copies of appropriate portions of this document can be made for a fee. Procedures other than those we use may be acceptable, however.

Sincerely,

John Winters, Chief
Water Quality Surveillance
and Standards Branch
Office of Water Management

SEG LABORATORIES, INC.

SEG LABORATORIES, INC.
1120 MAY STREET
LANSING, MI 48906
PHONE - 517-374-6800

SEG Engineers & Consultants, Inc.
36 S. Pennsylvania
Indianapolis, IN 46204
Mr. Howard Dillon

PROJECT NUMBER

Location		Lab No	Time Sampled	Date Sampled	Date Received
SITE C SURFACE	BISHOFF RESERV	7606	0	08/30/89	08/31/89
SITE C 8' 1' OFF BOTTOM	BISHOFF RESERV	7607	0	08/30/89	08/31/89
SITE C 5 FT.	BISHOFF RESERV	7605	0	08/30/89	08/31/89

ANALYTICAL REPORT
DATE REPORTED 09/29/89

TEST	UNITS	LAB NO. 7606	LAB NO. 7607	LAB NO. 7605
pH		*	*	7.91
Ammonia-N	mg/L	<0.05	0.09	<0.05
Nitrate-N	mg/L	<0.10	<0.10	<0.10
Total Phosphorus	mg/L	0.049	0.060	0.010
Dissolved Phosphorus	mg/L	<0.002	0.020	0.010
Conductivity	umhos/cm	231	232	228
Fecal Coliform Bacteria	Cts/100mls	>200	---	---
Total Kjeldahl Nitrogen	mg/L	0.79	0.75	1.4
Total Suspended Solids	mg/L	43	44	12
Temperature		83.5	78.3	79.5
Dissolved Oxygen	mg/L	10.40	7.13	9.34

PROJECT MANAGER Lori A. Vachon
LORI A. VACHON

Location	Lab No	Time Sampled	Date Sampled	Date Received
SITE B CTR CHANNEL UNDER POWERLINE	7610		8/30/89	8/31/89
SITE C SEDIMENT	7611		8/30/89	8/31/89

TEST	UNITS	LAB NO. 7610	LAB NO. 7611
PURGEABLE HALOCARBONS		EPA 8010	EPA 8010
Dichlorodifluoromethane	ug/kg	<50	<50
Chloromethane	ug/kg	<50	<50
Vinyl chloride	ug/kg	<50	<50
Bromomethane	ug/kg	<50	<50
Chloroethane	ug/kg	<10	<10
Trichlorofluoromethane	ug/kg	<10	<10
1,1-Dichlorethene	ug/kg	<10	<10
Methylene chloride	ug/kg	<10	<10
trans-1,2-Dichloroethene	ug/kg	<10	<10
1,1-Dichloroethane	ug/kg	<10	<10
Chloroform	ug/kg	<10	<10
1,1,1-Trichloroethane	ug/kg	<10	<10
Carbon tetrachloride	ug/kg	<10	<10
1,2-Dichloropropane	ug/kg	<10	<10
Bromodichloromethane	ug/kg	<10	<10
2-Chloroethylvinyl ether	ug/kg	<10	<10
cis-1,3-Dichloropropene	ug/kg	<10	<10
trans-1,3-Dichloropropene	ug/kg	<10	<10
1,1,2-Trichloroethane	ug/kg	<10	<10
Tetrachloroethene	ug/kg	<10	<10
Dibromochloromethane	ug/kg	<10	<10
Chlorobenzene	ug/kg	<10	<10
Bromoform	ug/kg	<10	<10
1,1,2,2-Tetrachloroethane	ug/kg	<10	<10
1,3-Dichlorobenzene	ug/kg	<10	<10
1,4-Dichlorobenzene	ug/kg	<10	<10
1,2-Dichlorobenzene	ug/kg	<10	<10
PURGEABLE AROMATICS		EPA 8020	EPA 8020
Benzene	ug/kg	<10	<10
Toluene	ug/kg	<10	<10
Ethylbenzene	ug/kg	<10	<10
Chlorobenzene	ug/kg	<10	<10
1,3-Dichlorobenzene	ug/kg	<10	<10
1,4-Dichlorobenzene	ug/kg	<10	<10
1,2-Dichlorobenzene	ug/kg	<10	<10

SEG LABORATORIES, INC.

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SEG ENGINEERS & CONSULTANTS, INC.

PROJECT NUMBER

SEG LABORATORIES, INC.
1120 MAY STREET
LANSING, MI 48906
PHONE - 517-374-6800

Engineers & Consultants, Inc.
. Pennsylvania
anapolis, IN 46204
Howard Dillon

Location		Lab No	Time Sampled	Date Sampled	Date Received
SITE B CTR-CHANNEL UND.PL	BISHOFF RESERV	7610	0	08/30/89	08/31/89
SITE C SEDIMENT	BISHOFF RESERV	7611	0	08/30/89	08/31/89

ANALYTICAL REPORT
DATE REPORTED 10/13/89

TEST	UNITS	LAB NO. 7610	LAB NO. 7611
Phosphorus	mg/kg	79	2.1
Grease	mg/kg	1800	570
l	mg/kg	1.740	3.44
Kjeldahl Nitrogen	mg/kg	320	390
de	mg/L	0.05	0.19
ic	mg/kg	1.8	2.5
um	mg/kg	<0.20	<0.20
ium	mg/kg	8.8	9.0
r	mg/kg	24	18
	mg/kg	9,200	8,400
	mg/kg	4.8	4.9
nese	mg/kg	230	130
ry	mg/kg	<0.005	<0.005
l	mg/kg	0.70	<0.40
ium	mg/kg	0.13	0.04
	mg/kg	<0.30	<0.30
	mg/kg	26	25
:ides		ATTACHED	ATTACHED
PCBs		ATTACHED	ATTACHED

BISHOFF RESERVOIR

SITE A

DEPTH	TEMP	COND
Surface	82.4	290
1 Ft.	79.2	
2 Ft.	78.5	253
3 Ft.	79.9	
4 Ft.	78.2	(255)
5 Ft.	78.4	248
6 Ft.	77.5	251
7 Ft.	77.1	251
8 Ft.	77.1	250
9 Ft.	76.5	249
10 Ft.	77.2	251
11 Ft.	75.9	
12 Ft.	75.7	248
13 Ft.	74.5	252
14 Ft.	72.9	266
15 Ft.	72.4	269 (H_2S Odor)
16 Ft.	72.5	266
17 Ft.	72.2	273
18 Ft.	69.7	289
19 Ft.	67.2	309
20 Ft.	67.2	
21 Ft.	67.0	
22 Ft.	64.5 (1 Ft. from Bottom)	

TOTAL DEPTH = 22.5 Feet

BISHOFF RESERVOIR

SITE B

DEPTH	TEMP	COND
Surface	82.2	231
1 Ft.	81.3	231
2 Ft.	80.0	227
3 Ft.	79.5	226
4 Ft.	79.4	227
5 Ft.	78.0	226
6 Ft.	77.4	225
7 Ft.	77.5	226
8 Ft.	77.7	226
9 Ft.	77.4	226
10 Ft.	76.9	227

TOTAL DEPTH = 10.5 Feet

BISHOFF RESERVOIR

SITE C

DEPTH	TEMP	COND
Surface	83.5	231
1 Ft.	82.1	229
2 Ft.	81.1	228
3 Ft.	80.8	227
4 Ft.	79.7	226
5 Ft.	79.5	226
6 Ft.	79.0	226
7 Ft.	77.9	226
8 Ft.	78.3	227

TOTAL DEPTH = 9 Feet

Location	Lab No	Time Sampled	Date Sampled	Date Received
SITE B CTR CHANNEL UNDER POWERLINE	7610		8/30/89	8/31/89
SITE C SEDIMENT	7611		8/30/89	8/31/89

TEST	UNITS	LAB NO. 7610	LAB NO. 7611
ORGANOCHLORINE PESTICIDES			
Aldrin	mg/kg	<1.0	<1.0
a-BHC	mg/kg	<1.0	<1.0
b-BHC	mg/kg	<1.0	<1.0
g-BHC	mg/kg	<1.0	<1.0
y-BHC	mg/kg	<1.0	<1.0
Chlordane	mg/kg	<1.0	<1.0
4,4'-DDD	mg/kg	<1.0	<1.0
4,4'-DDE	mg/kg	<1.0	<1.0
4,4'-DDT	mg/kg	<1.0	<1.0
Dieldrin	mg/kg	<1.0	<1.0
Endosulfan I	mg/kg	<1.0	<1.0
Endosulfan II	mg/kg	<1.0	<1.0
Endosulfan sulfate	mg/kg	<1.0	<1.0
Eldrin	mg/kg	<1.0	<1.0
Endrin aldehyde	mg/kg	<1.0	<1.0
Heptachlor	mg/kg	<1.0	<1.0
Heptachlor epoxide	mg/kg	<1.0	<1.0
Toxaphene	mg/kg	<1.0	<1.0
Arochlor-1016	mg/kg	<1.0	<1.0
Arochlor-1221	mg/kg	<1.0	<1.0
Arochlor-1232	mg/kg	<1.0	<1.0
Arochlor-1242	mg/kg	<1.0	<1.0
Arochlor-1248	mg/kg	<1.0	<1.0
Arochlor-1254	mg/kg	<1.0	<1.0
Arochlor-1260	mg/kg	<1.0	<1.0

PORJECT MANAGER Lori A. Vachon

LORI A VACHON

Location		Lab No	Time Sampled	Date Sampled	Date Received
SITE A 20 FT.	BISHOFF RESERV	7600	0	08/30/89	08/31/89
SITE A 1 FT.FROM BOTTOM	BISHOFF RESERV	7601	0	08/30/89	08/31/89

ANALYTICAL REPORT
DATE REPORTED 09/29/89

TEST	UNITS	LAB NO. 7600	LAB NO. 7601
pH		6.43	6.98
Ammonia-N	mg/L	4.2	5.5
Nitrate-N	mg/L	<0.10	<0.10
Total Phosphorus	mg/L	0.380*	0.020
Dissolved Phosphorus	mg/L	0.380*	0.010
Conductivity	umhos/cm	294	287
Fecal Coliform Bacteria	Cts/100mls	---	---
Total Kjeldahl Nitrogen	mg/L	3.6	5.0
Total Suspended Solids	mg/L	40	50
Temperature		69.2	64.5
Dissolved Oxygen	mg/L	<1.0	<1.0

PROJECT MANAGER Lori A. Vachon
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Mr. Howard Dillon

PROJECT NUMBER

Location		Lab No	Time Sampled	Date Sampled	Date Received
SITE B SURFACE	BISHOFF RESERV	7604	0	08/30/89	08/31/89
SITE B 5 FT.	BISHOFF RESERV	7602	0	08/30/89	08/31/89
SITE B 10 FT.	BISHOFF RESERV	7603	0	08/30/89	08/31/89

ANALYTICAL REPORT
DATE REPORTED 09/29/89

TEST	UNITS	LAB NO. 7604	LAB NO. 7602	LAB NO. 7603
pH		7.94	7.66	7.50
Ammonia-N	mg/L	<0.05	<0.05	0.14
Nitrate-N	mg/L	<0.10	<0.10	<0.10
Total Phosphorus	mg/L	0.010	0.020	0.060
Dissolved Phosphorus	mg/L	<0.002	0.006	0.010
Conductivity	umhos/cm	228	234	240
Fecal Coliform Bacteria	Cts/100mls	>200	---	---
Total Kjeldahl Nitrogen	mg/L	1.4	1.4	1.4
Total Suspended Solids	mg/L	6	14	9
Temperature		82.2	78.0	76.9
Dissolved Oxygen	mg/L	11.4	11.4	2.12

PROJECT MANAGER Lori A. Vachon
LORI A. VACHON

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A Snell Environmental Group Company

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Mr. Howard Dillon

PROJECT NUMBER

Location		Lab No	Time Sampled	Date Sampled	Date Received
SITE A SURFACE	BISHOFF RESERV	7608	0	08/30/89	08/31/89
SITE A 5 FT.	BISHOFF RESERV	7597	0	08/30/89	08/31/89
SITE A 10 FT.	BISHOFF RESERV	7598	0	08/30/89	08/31/89
SITE A 15 FT.	BISHOFF RESERV	7599	0	08/30/89	08/31/89

ANALYTICAL REPORT
DATE REPORTED 09/29/89

TEST	UNITS	LAB NO. 7608	LAB NO. 7597	LAB NO. 7598	LAB NO. 7599
pH		9.40	7.38	7.14	7.45
Ammonia-N	mg/L		<0.05	0.17	0.72
Nitrate-N	mg/L		<0.10	<0.10	<0.10
Total Phosphorus	mg/L		0.040	0.050	0.040
Dissolved Phosphorus	mg/L		0.004	0.004	0.007
Conductivity	umhos/cm	290	229	224	236
Fecal Coliform Bacteria	Cts/100mls	>200	---	---	---
Total Kjeldahl Nitrogen	mg/L		1.5	1.5	1.8
Total Suspended Solids	mg/L		18	12	20
Temperature		82.4	78.4	77.2	72.4
Dissolved Oxygen	mg/L	11.8	4.50	1.10	1.05

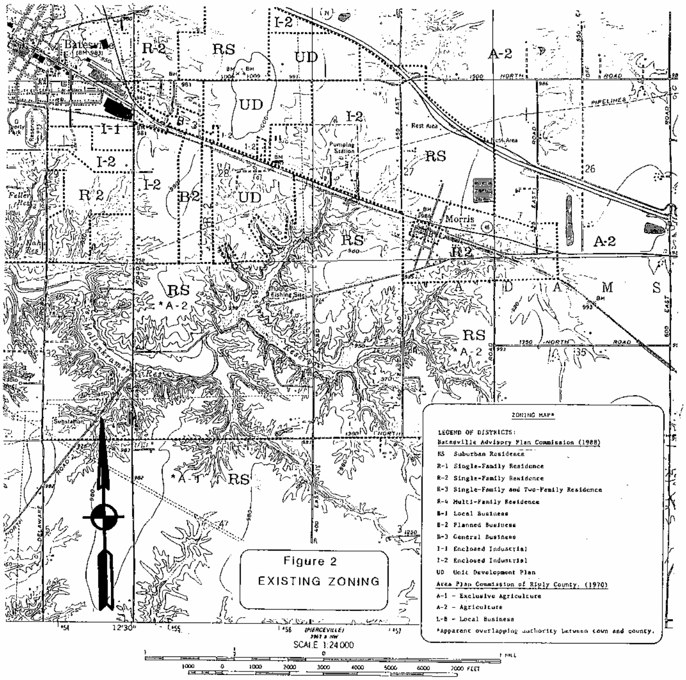

Figure 2
EXISTING ZONING

Table 6

DATA ON INDIANA PUBLIC WATER SUPPLIES

Community Served and/or Public Water Utility	Population / Population Served	Number of Services	Ownership	Source of Supply	Rated Plant Capacity MGD / Average Daily Use MG	Average Daily Use Max. Month MG / Maximum Daily Use MG	Treatment	Finished Water Storage MG / Gravity / Pumped
1	2	3	4	5	6	7	8	9
21 Auburn	8,122 8,700	3,451	M	North Street Plant Four GPW 175'-245', G	2.000 1,000	 2.000	ID-AflDcCp FapDc	
				South Wayne Street Plant Six TW 175'-245', G	4.000 0.500	 1.700	ID-AflDpFpcDc	
				System Total	6.000 1.500	 3.700		1.000 None
22 Aurora	3,816 5,600	1,900	M	Three GPW 90'-100', G Two tubular 23' G (standby)	2.000 0.857	0.997 1.182	DV-DcVa	0.650 None
23 Avilla	1,272 1,257	465	M	Three TW 117', G	0.360 0.125	0.132 0.203	10-AflDcFrs	0.150 None
24 B & B Water Project, Inc.	— 3,202	1,186	N	Purchase from Bloomington	 0.302	0.395	D-Dh	0.200 None
25 Baer Field Municipal Airport	— 3,000	60	M	Three TW 220'-260' R	1.188 0.232	0.294 0.442	HID-AflFspzDc	None 0.500
26 Bainbridge	644 714	335	M	Two TW 120', R	0.555 0.053	0.074 0.097	IDV-AlDcFapVt	0.150 None
27 Bargersville	1,647 7,500	2,500	M	Two GPW 85', 103', S&G	1.440 0.601	0.713 1.093	IDV-AlClFraFom DcVa	0.800 0.250
28 Batesville	4,152 4,800	1,601	M	Impoundments: Bischoff-700MG MollenKramer-44MG Oser-Hahn-75MG Park-55MG	2.000 0.918	1.085 1.486	PDV-XcAfDc CalMpSoFgs TcPlDcVt	0.650 0.300
29 Battle Ground	812 800	330	M	Two TW 140', S&G	0.329 0.135	0.176 0.226	DV-BpDcVt	0.050 None
30 Bean Blossom-Patricksburg Water Corp.	— 4,550	1,685	N	Four TW 87'	0.690 0.492	0.590 0.676	DV-DcVt	0.200 None
31 Bedford	14,410 14,000	5,500	M	Illinois Street Plant East Fork White River	5.000		PV-XcCaDcTcMs SoFrsDcVs	1.000
				M Street Plant (standby) Salt Creek	3.000		P-DcCalPlMpTcSo FrsDc	0.500
				System Total	8.000 3.947	4.463 5.550		1.000 1.500
32 Berne	3,300 3,500	1,300	M	Three TW R also purchase raw water from Decatur	0.864 0.350	0.410 0.776	HID-AfDcFapzDc	0.550 None
33 Bethany Water Fund	— 75	22	N	One TW 80', G	0.060 0.007		D-Dh	0.055 None
34 Bicknell	4,713 3,700	1,800	M	Five 3-GPW 64'-66', S&G	0.720 0.658	0.699 0.936	IDHV-AfDcFrzDcVt	0.300 0.100
35 Big Walnut Water Corp.	— 282	120	N	Purchase from Crawfordsville	 0.023	0.025 0.029	None	None None
36 Birdseye	533 790	360	M	Purchase from St. Anthony	 0.048	0.055	None	0.090 None
37 Black Oak SD	— 3,663		P	Purchase from Hammond	 0.020	0.023	None	None None

CHEMICAL CHARACTERISTICS (Raw Water / Finished Water)

	pH	HARDNESS as $CaCO_3$ mg/l	CALCIUM as Ca mg/l	MAGNESIUM as Mg mg/l	SODIUM as Na mg/l	POTASSIUM as K mg/l	IRON as Fe mg/l	MANGANESE as Mn mg/l	ALKALINITY as $CaCO_3$ mg/l	CHLORIDES as Cl mg/l	SULFATES as SO_4 mg/l	PHOSPHATES as PO_4 mg/l	NITRATES as N mg/l	FLUORIDES as F mg/l
21	7.0-8.0 8.2	278-320 268	70-77 69	20-33 23	17-18 17	1.6-1.8 1.6	1.2-2.2 <0.05	0.02-0.40 <0.02	291-334 300	45 11	<5-28 6	<0.09-0.24 <0.09	<0.1-0.3 0.4	0.8-1.0 1.0
22	6.8 6.9	424 422	116 119	33 30	11 10	0.90 0.90	<0.10 <0.10	0.02 <0.02	232 230	26 27	150 160	0.12 <0.09	1.8 1.7	1.0 0.7
23	7.6 7.8	338 332	77 77	35 34	19 19	2.0 1.8	2.1 0.10	0.02 0.03	336 340	2 <5	18 24	<0.09 <0.09	0.2 0.2	1.1 1.1
24	7.2	145	49	5	8	3.0	0.10	<0.02	100	18	36	<0.09	0.8	0.8
25	7.7	169	38	18	150	2.2	<0.05	<0.20	291	25	180	<0.09	0.2	0.8
26	7.4-7.5 7.7	335 331	74 74	36 35	19-24 24	2.9 3.0	0.11-0.29 0.09	0.02 <0.02	389-409 374	5 10	<5 <5	0.09 0.15	<0.1 0.2	0.4 0.9
27	7.4 7.8	381 134	102 32	30 26	60 68	2.4 0.08	2.7 <0.10	0.09 <0.02	296 192	99 25	75 52	0.20 0.12	<0.1 <0.1	0.2 0.9
28	7.7-8.7 7.7	88-108 118	27-31 38	5-7 6	6-8 7	4.7 4.1	<0.05 <0.05	0.07-0.23 <0.02	67-84 70	12-14 16	21-27 35	0.10-0.20 <0.09	0.2-0.5 <0.1	0.2 1.1
29	7.3-7.4 7.3	316-324 322	75-82 82	29-31 28	10-13 13	2.0-3.0 2.2	0.80-1.2 0.57	0.16 0.12	296-314 300	8-11 8	11-30 30	<0.09 4.3	0.1-0.3 0.4	0.3 1.0
30	7.4-7.7 7.4	298-458 412	82-123 110	23-36 34	9-30 22	1.0-1.1 1.3	0.10-3.0 <0.05	0.02-0.11 0.07	276-328 326	7-43 35	29-125 79	<0.09-0.80 0.45	<0.1-1.6 0.9	0.3-0.4 0.8
31	6.7-8.1 7.9	92-208 208	29-79 65	5-24 11	2.4-8.7 11	1.8-6.4 3.9	0.19-4.6 <0.05	0.03-0.22 <0.02	68-238 120	8-25 25	30-48 62	0.2-0.96 <0.09	0.7-4.8 2.3	0.1-0.3 0.7
32	7.0-7.4 7.9	532-792 70	131-195 16	48-74 7	33-71 350	1.9-3.7 0.90	1.2-6.7 <0.05	<0.02-0.04 <0.02	170-324 162	11-54 12	340-670 570	0.10-0.50 <0.09	<0.1 0.7	1.0-1.5 1.4
33	7.4 7.4	336 342	86 86	29 31	13 13	2.0 2.0	1.8 0.60	0.07 0.03	302 302	4 10	39 43	<0.10 <0.10	0.3 0.4	0.3 0.3
34	7.2-7.4 7.5	356-536 168	97-152 46	21-38 13	5-20 91	0.50 0.40	3.4-8.4 <0.05	0.32-0.46 0.03	260-290 271	15-17 18	49-255 60	0.45-1.5 <0.09	<0.1-0.8 0.2	0.2 0.2
35														
36	8.2	74	22	4	4	3.0	0.10	<0.02	30	11	40	<0.09	1.0	<0.2
37														

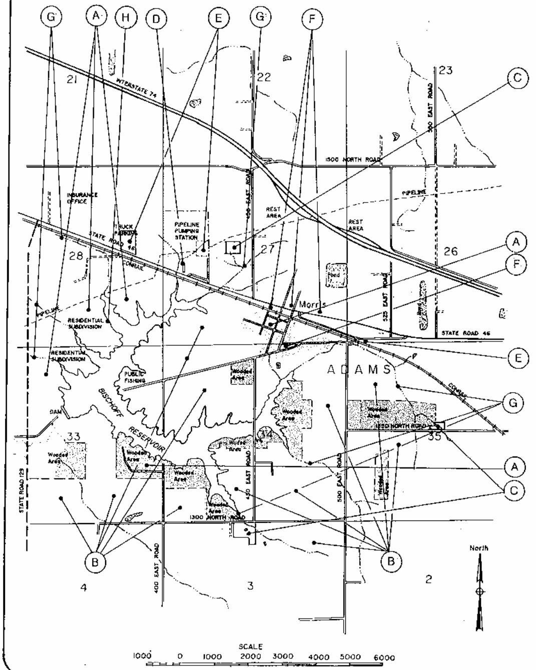

Figure 8

POTENTIAL SOURCES OF POLLUTION

(A) Pollution incidental to residential areas, including septic system overflow and contaminated surface water runoff.

(B) Pollution incidental to agricultural activities, including soil erosion and surface water runoff containing herbicides, pesticides, and fertilizer.

(C) Feed lots.

(D) Pollution incidental to industrial activity, including industrial process chemicals.

(E) Surface water drainage containing residues of petroleum products and fertilizer.

(F) Pollution incidental to commercial activity.

(G) Pollution resulting from soil erosion in inlet streams.

(H) Erosion of reservoir banks.

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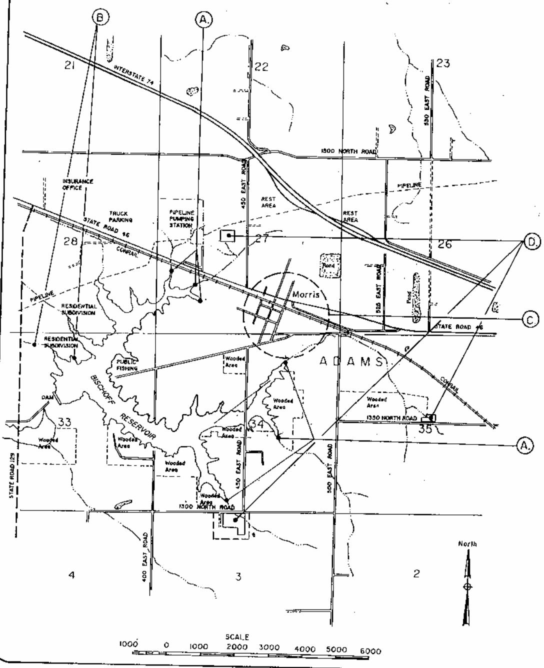

Figure 17

PROPOSED ABATEMENT MEASURES

(A.) Construct siltation traps.

(B.) Stabilize erosion along reservoir banks and inlet channels.

(C.) Connect sewers within the Town of Morris to the Batesville sewer system.

(D.) Improve methods of animal waste collection and disposal at the feed lots. Control surface water runoff.

* (E.) Formulate an "Erosion and Sedimentation Control Plan", applicable to future residential development around the lake. Develop and implement a county wide erosion control ordinance.

(F.) Draw the reservoir down.

* Recommendation "E" applies to all future development in the vicinity of the reservoir. This recommendation was taken from the "Urban Development Planning Guide for Erosion & Sediment Control", Hoosier Heartland Resource Conservation and Development Council, Inc. Fourth Edition.